DOCUMENT RESUME

ED 261 218 CE 042 422

AUTHOR Karmos, Joseph S.; Karmos, Ann H.
TITLE Strategies for Problem Solving.
INSTITUTION Southern Illinois Univ., Carbondale.
SPONS AGENCY Illinois State Board of Education, Springfield. Dept. of Adult, Vocational and Technical Education.
PUB DATE 85
NOTE 95p.; For related documents, see ED 250 478 and CE 042 423.
PUB TYPE Guides - Classroom Use - Guides (For Teachers) (052)

EDRS PRICE MF01/PC04 Plus Postage.
DESCRIPTORS Classroom Techniques; Course Content; Curriculum Development; *Educational Needs; Educational Trends; Futures (of Society); *Guidelines; Interpersonal Competence; *Models; Postsecondary Education; *Problem Solving; Secondary Education; *Skill Development; Teaching Methods; Vocational Education

ABSTRACT

Problem-solving skills are becoming increasingly important in the workplace, and more schools are including them in the curriculum. Knowledge of problem solving will be critical to a work force that is dealing with advanced technology, yet many students have yet to master these skills. Based on this premise, this guide attempts to show how students can be taught problem-solving skills and provides a model for problem solving, along with examples. Following an introduction, the guide contains seven sections. The first section proposes a five-step model for problem solving, and addresses the need for transferring these skills to all areas of life. In the second section, general guidelines for problem solving are given, including those developed by deBono and Whimbey and Lochhead. The third section focuses on some specific problem-solving strategies, such as thinking aloud, trial and error, working backwards, finding all the possibilities, time management, logical and critical reasoning, and gathering and analyzing data. The fourth section extends the five-step model for problem solving, while the section following discusses higher-order problem-solving skills and suggests simulations. In the sixth section, interpersonal skills are examined, while the final section outlines problem solving in groups. References for further use are suggested throughout the guide. (KC)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

BEST COPY AVAILABLE

Strategies for Problem Solving

Illinois State Board of Education

Department of Adult Vocational and Technical Education

June 1985

ED261218

U.S. DEPARTMENT OF EDUCATION
NATIONAL INSTITUTE OF EDUCATION
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

☒ This document has been reproduced as received from the person or organization originating it.

☐ Minor changes have been made to improve reproduction quality.

• Points of view or opinions stated in this document do not necessarily represent official NIE position or policy.

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY

DGI

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

CE043422

STRATEGIES FOR PROBLEM SOLVING

Joseph S. Karmos and Ann H. Karmos

Southern Illinois University
at Carbondale

TABLE OF CONTENTS

	Page
PROBLEM SOLVING	1
A MODEL FOR PROBLEM SOLVING	4
The Need for Transfer	7
STRATEGIES FOR SOLVING PROBLEMS -- GENERAL GUIDELINES	11
Guidelines from deBono	11
Guidelines from Whimbey and Lochhead	13
The Problem Solver's Knowledge Base	16
SOME SPECIFIC PROBLEM SOLVING STRATEGIES	19
Thinking Aloud	19
Trial and Error	21
Working Backwards	23
Finding all the Possibilities	25
Time Management	28
Logical and Critical Reasoning	29
Gathering, Recording and Analyzing Data	34
THE FIVE STEP MODEL EXTENDED FOR PROBLEM SOLVING	41
HIGHER ORDER PROBLEM SOLVING SKILLS	47
Simulations	55
INTERPERSONAL SKILLS FOR BEING EFFECTIVE WITH INDIVIDUALS AND IN GROUPS	58
SKILL: Awareness of Self and Others	58
SKILL: Recognizing Problem Ownership	60
SKILL: Avoiding Roadblocks to Communication	62
SKILL: Listening	67
SKILL: Assertive Statements	72

Page

PROBLEM SOLVING IN GROUPS 75

Five Step Model for Solving Problems Resulting from a Conflict of Needs 78

The Need for Interpersonal Skills for Negotiating 84

Conclusion 84

PROBLEM SOLVING

The importance of problem solving in vocational education is receiving more national attention now than ever before. For example, Daniels and Karmos (1983) found that except for the three R's, problem solving was listed most frequently in the literature and by employers as an essential skill for dealing with the future. Michael Timpane, in his report of corporations and public education, emphasized the need for teaching young people problem solving skills so they will be ready for further education and training (Timpane, 1982).

Roy Forbes, Director of the assessment and evaluation division of the Education Commission of the states, predicted that by 1990 between 900,000 and 2,000,000 high school graduates will not possess the problem solving skills required for employment in a highly technological society (Whimbey & Lochhead, 1984). Pratzner (1984) has stated that "The first priority is for secondary level vocational education to offer good education in reading, writing, computing, listening, and problem solving" (p. 6). Lemons (1984) concluded that the education required to prepare individuals for post-secondary education and training for high-technology occupations must include critical thinking and reasoning skills (p. xii).

Not enough problem solving is occurring in classrooms. In the April, 1983 Kappan, John Goodlad remarked that "teacher talk" was by far the dominant classroom activity. "Teachers rarely encouraged student-to-student dialogue or provided opportunities for students to work collaboratively in small groups or to plan, set goals, determine alternative ways of achieving these goals, and the like. The emphasis was on

recall, not on problem solving or inquiry" (p. 552). Goodlad went on to say that each of the 50 states believes in problem-solving instruction but very few are doing much with it.

Ann Brown from the University of Illinois conducted an interview with Edward Binet (Brown, 1984) on the teaching of problem solving skills. Binet said:

> What I object to in traditional classes is that it is the teacher who produces, and the student who passively listens. Such a lesson has two faults: It does not impress the student other than by its verbal function, it gives him words instead of making him deal with actual objects, and it appeals only to his memory, reducing him to a passive state. He doesn't judge, doesn't think, doesn't invent, and doesn't produce. He needs only to retain. His aim is to repeat without mistake, make his memory work, know what is in the lecture, in the textbook and reproduce it. The results of such practices are deplorable: E.g., a lack of curiosity for what is not in the book or lecture; a tendency to look for the truth only in the book, the belief that one is doing some original research by going through a book, too much respect for the writer's opinion, a lack of interest in the world and the lessons it gives, a naive belief in the power of simple formulas, a difficulty to adapt oneself to contemporary life, and above all, a static regimentation unwelcome at a period when social evolution is so fast. (pp. 14-15)

Something is being done about problem solving by business and industry. In 1983, General Motors trained approximately 50 percent of its employees in problem solving skills. Kathy Long, Director of Research and Development for GM, said in a personal interview (1983) that the training has been successful, that productivity and positive attitudes have both increased, and that General Motors is going to devote more time and money to problem solving training. The training has improved worker competency, enabled workers to diagnose and solve job-related problems, taught them to examine their own behavior and consequences of it, and has helped workers to be more cooperative with each other in solving problems (Guest, 1979). The Center for Public Resources, in its report Basic Skills in the United States Work Force (1982), identified other corporations and also schools which are currently involved in problem solving training.

A MODEL FOR PROBLEM SOLVING

For students to hold jobs, to be retrained and in general to adapt to a constantly accelerating rate of change in their lives, they will need strategies for how to attack and solve problems. Possession of at least one general model for solving problems is one essential strategy. There are many different models. The one we have developed is given below. It is based on problem solving models from General Motors (Kolb & Baker, 1980), from G. Polya's book How to Solve It (1957), and from Thomas Gordon's book Teacher Effectiveness Training (1974). Our model has five steps.

Five Step Model for Solving Problems

1. Understand the Problem
   - If people are involved, then there should be explicit agreement among the people on what the problem is.
   - If appropriate, analyze the problem for possible causes. (In mathematics causes are usually not involved.)
2. Brainstorm for Possible Solution Strategies
   - No evaluations or judgments should occur here. This should be a free-wheeling act of generating ideas.
3. Choose a Tentative Solution Strategy
   - For "people" problems, consequences of behaviors and solutions must be carefully considered.
   - If people are working out an interpersonal problem, then the tentative strategy will likely be a compromise.

4. Carry Out the Tentative Strategy

   ° In implementing most strategies involving people, it is important to decide, "Who, does What, When."

5. Learn

   ° Immediately and over time think about what can be learned from the experience. What are the implications of what has been done?

   ° If appropriate, evaluate the effectiveness of the solution. (You may have to start over.)

To demonstrate the versatility of this model, consider the following three examples which have been solved by teachers, students, school administrators, and business people using the five-step model. The first problem is from a General Motors training manual. The second problem is from the Institute for the Advancement of Philosophy of Children. The third problem is taken from the 1980 Yearbook for the National Council of Teachers of Mathematics.

Example 1.

Your company has just obtained a one-year contract for delivering six truckloads of hazardous materials a month. All six trucks are enroute, and this is the first time any one of you has driven this busy road. All trucks are identical though they are loaded differently. You will make 11 more deliveries this year.

The second truck is immediately behind the first truck, which is pulling a forklift. Four other trucks are about 15 minutes behind on the same road. The first truck went under a concrete underpass with no problem, but the second truck got stuck. Comparing

the shipping documents you realize the first truck is carrying 400 containers weighing 50 pounds each. The second truck carries 300 larger containers that only weigh 40 pounds each. The cargo is on pallets. There is an open truck service station ahead. It has a fully equipped wrecker for servicing trucks on the highway. All the trucks must arrive at the destination 20 miles ahead within one hour or your company will have to pay penalties. There is an alternate route behind you but it is 10 miles longer with equally heavy traffic. You are members of the crew driving the stuck truck. What will you do?

Example 2.

Your best friend won't graduate if she doesn't turn in a long overdue paper. But she's got some kind of hang-up about it and can't write it, so now the two of you are wondering if maybe you should write it for her. You have a number of options. Which one would you choose?

Example 3.

James and Judy both work part-time in a cafeteria that is open seven days a week. James works one day and then has three days off before he works again. Judy works one day and then has four days off. James works this Monday and Judy works this Tuesday. Show the days that James and Judy will work on the same day.

At the beginning, we have our students follow the Five Step Model, step by step. Later on they are encouraged to freely use their own

creativity and intuition to solve problems since no single model is directly applicable to all problems.

The Five Step Model is currently being used by students for their academic work and for their interpersonal lives. But is the model also practical for the work place? The answer is "yes." Students use it in their part-time jobs, and General Motors uses it to get people to work together to solve problems. Employees cooperate in GM's Employee Participation Groups to solve on-the-job problems. In a 1983 personal interview, Kathy York of GM's Research and Development Division stated that competition among workers often turns out to be a liability. "They work separately against each other. We need our employees to work together to solve problems. That will increase their job competence." The problems that the groups focus on are not generally psychological ones; they are job-related problems. Workers, supervisors, managers, and executives get involved in the groups. Whoever is being affected by the problem or the solution is in the group. They use a model very similar to the Five Step Model.

The Need for Transfer

For general problem solving, a model is necessary but it is not sufficient. Transfer is one of the deficiencies. Schools teach problem solving, but most students have difficulty transferring their problem solving capabilities from one setting to another (Johnson, 1984; Snowman, 1984). A recent experience made this "breakdown in transfer" more meaningful to us. We were conducting a workshop on problem solving skills and during the last half of the workshop a high school math teacher who systematically uses Polya's problem solving model remarked

that he did not know what he was going to do about equipment and visuals since his school's budget had declined each of the past three years. There was a slight pause, then one of the workshop participants asked, "Have you thought about applying your problem solving model to that problem?" The teacher said, "No." Why didn't this math teacher transfer his problem solving skills from math to the situation of a reduced budget and probably less math equipment? We believe there are two major reasons for lack of transfer.

1. Not enough diverse kinds of problems are given to students to encourage transfer over a wide range of settings. Only math problems are given, or science problems, or social studies problems, and so on. These problems are context bound. They are too similar to each other. There are many commercial programs for teaching problem solving, and they provide a wide variety of problems. The June 1983 issue of the Kappan listed more than 30 programs, video-taped presentations, computer-assisted instruction, instructional programs for teachers, and materials for student use. Other excellent sources are:
   - The Edward deBono School of Thinking, P. O. Box 711, Larchmont, NY 10538.
   - Institute for the Advancement of Philosophy for Children, Montclair State College, Upper Montclair, NJ 07043.
   - The Productive Thinking Program from the Charles E. Merrill Publishing Company in Columbus, OH.
   - Problem Solving and Comprehension by Arthur Whimbey and Jack Lochhead, The Franklin Institute Press, Philadelphia, 1979.

- More Life Skills by Joan Hearn, Advanced Development Division, Employment and Immigration, Ottawa, Canada K1A 0J9, 1982.
- Problem Solving in School Mathematics, 1980 Yearbook, National Council of Teachers of Mathematics, Reston, VA.
- Instrumental Enrichment by Reuven Feuerstein, University Park Press, Baltimore, 1980.
- The New MCAT Student Manual (Quantitative Skills) from the Association of American Medical Colleges, Washington, DC, 1984.
- Medical College Admission Test (Quantitative Skills) by Morris Bramson and Lawrence Solomon, Arco Publishing, Inc., NY, 1982.
- A Complete Preparation for the New MCAT, Vol. II (Quantitative Skills) by Beryl Brain, Drew Love, and Philip Kelleher, Health Professional Education Service, Inc., Bethesda, MD, 1981.

If Molitor (1981) is right in his predictions that by the year 2000 76% of the work force will be in information/knowledge/education enterprises and other services, then the last three references will be particularly good sources of problems to prepare students for the future.

2. Most students are not explicitly taught strategies for solving problems. Some strategies are: Using a model, reading information carefully, breaking the problem into manageable parts, and making a sketch. We have taught strategies to students,

they have learned them, and they have improved their problem solving.

STRATEGIES FOR SOLVING PROBLEMS -- GENERAL GUIDELINES

Guidelines from deBono

Edward deBono has formulated guidelines for good thinking and problem solving. His system has been adopted by corporate executives, taught in schools, and studied by government officials from more than a score of countries. Here are basic tools taken mostly from deBono's The Learning-To-Think Coursebook (1982).

1. Consider all Factors and Don't Limit Perceptions.

A conscious effort should be made to think of everything that might be relevant for solving the problem. Suppose you're thinking about buying a new house. Consider all factors to be sure you ask all the right questions. While obvious issues such as size, cost and layout are bound to come to mind, without a deliberate effort to list every relevant factor you might overlook others. How good is TV reception? Is there a local leash law? Can the pipes be drained quickly in case of a power failure in freezing weather?

Recall our discussion about the math teacher who didn't think about using a problem solving model from math class to help him solve the problem of a smaller budget and at the same time a need for more learning resources. He limited his point of view--he had access to more than he was using. This is not uncommon for problem solving. Try this experiment: Look around the room for red objects. (Don't read on until you've done so.) Now close your eyes and ask yourself how many green objects there are. Look again. Surprised? It was your focused attention on red that kept you from noticing things of another color.

Even after using various tools of thought, you may not have found a satisfactory solution to your problem. The key to finding alternatives is to look for possibilities outside your usual thinking patterns. Edison, in searching for a light-bulb filament, tried thousands of unlikely materials including cork, fishing line and tar, before succeeding with a strip of carbonized cardboard.

2. Consequences and Sequels.

One of the traits that makes us different from animals is our ability to imagine the outcome of our actions. But we can greatly improve this ability by learning to use it in a systematic way. The deBono technique is to image the probable outcome of a decision at four distances in the future: Immediate, short term (1 to 5 years), medium term (5 to 25 years) and long term (over 25 years). By weighing the consequences of thoughts and actions, people can be less impulsive and make better decisions for themselves, based upon careful thought and not on quick emotion.

3. Aims, Goals, Objectives.

An often unused tool of better thinking is the practice of making a list of reasons for doing a particular thing. Often people assume they know what their goals are, but often they have hidden or unconsidered goals that get in their way. Also, people will often just "act out" without considering whether the behavior will get them what they want.

Setting priorities and goals can help people be more efficient. Sometimes there are so many things to do that it is overwhelming. To sit down and list the first priority, then the second, etc., can help the tasks become manageable.

Defining goals can also help lead to creative solutions to problems. DeBono tells of a grandmother trying to knit while her yarn was being tangled by the family toddler. Exasperated, she put him in his playpen, but he howled so loudly that she had to take him out. Then she realized that her goal wasn't to pen the child, but to separate him from her yarn. So she solved the problem by leaving him out--and climbing into the playpen herself.

4. Other Points of View.

Often problems involve a conflict with someone such as a friend, parent, boyfriend, or girlfriend. It is the mark of a good problem solver to be able to find a solution that will agree with the other person's viewpoint. It is particularly difficult to do when one is upset or angry. But if you can take another person's point of view at such times, then you have one of the major skills of good problem solvers.

DeBono tells of an incident where he bought a new car radio from a dealer who recommended it highly. It proved no better than the one it replaced. He was about to charge into the dealer's store and demand his money back, but it occurred to him to put himself in the dealer's place. Doing this, deBono saw how offended he'd be at having his judgment questioned. So he took a different tack and appealed to the dealer's sense of self-respect. The dealer exchanged the radio for a much better one, without charging the difference.

Guidelines from Whimbey and Lochhead

An additional set of guidelines for problem solvers is given by Arthur Whimbey and Jack Lochhead in Problem Solving and Comprehension

(1979). They describe the beliefs, practices, and tendencies of good problem solvers, and also the characteristics of poor problem solvers.

1. Positive Attitude.

Good problem solvers have a strong belief that academic reasoning problems can be solved through careful, persistent analysis. Poor problem solvers, by contrast, frequently express the opinion that "either you know the answer to a problem or you don't know it, and if you don't know it you might as well give up or guess." Poor problem solvers haven't learned that a problem may at first appear confusing and that the way to work the problem can be gradually analyzed and solved. Poor problem solvers lack both confidence and experience in dealing with problems through gradual and sometimes lengthy analysis. Problem solving progresses one step after another until the problem is solved.

2. Thoroughly Understanding the Data and the Problem.

Good problem solvers take great care to understand the facts and the relationships in a problem fully and accurately. They are most compulsive in checking whether their understanding of a problem is correct and complete. By contrast, poor problem solvers generally lack such an intense concern about understanding. For example, good problem solvers sometimes reread a problem several times until they are sure they understand it. Poor problem solvers, on the other hand, frequently miss a problem because they do not know exactly what it states. Poor problem solvers have not learned how important it is to try to be completely accurate in understanding all of the ideas of a problem.

In our problem solving classes we give students many problems which involve tabular and graphical data. We are surprised at the number of students that do not carefully analyze the given data before starting to

solve the problem. Instead, they just jump in and then jump to conclusions. It's a lethal habit. Focused effort must be made at the beginning to identify key information and eliminate extraneous data.

3. Breaking the Problem into Parts.

Good problem solvers have learned that analyzing complex problems and ideas often consists of breaking the ideas into smaller steps. They have learned to attack a problem by starting at a point where they can make some sense of it, and then proceeding from there. In contrast, poor problem solvers have not learned the approach of breaking a complex problem into sub-problems--dealing first with one step and then another.

4. Avoid Guessing.

Poor problem solvers tend to jump to conclusions and guess answers without going through all the steps needed to make sure that the answers are accurate. Sometimes they make intuitive judgments in the middle of a problem without checking to see whether the judgments are correct. At other times they work a problem part of the way, but then give up on reasoning and guess on an answer. Good problem solvers tend to work problems from beginning to end in small, careful steps.

The tendency for problem solvers to make more errors--to work too hastily and sometimes skip steps--can be traced to the three characteristics already discussed. First, poor problem solvers do not strongly believe that persistent analysis is an effective way (in fact the only way) to deal with problems. Thus their motivation to persist in working an entire problem precisely and thoroughly, until it is completely solved, is weak. Second, they tend to be careless in their reasoning. They have not developed the habit of continuously focusing and checking on the accuracy of their conclusions. And third, they have not learned

to break a problem into parts and work it step-by-step. As a result of these three characteristics, poor problem solvers have a strong tendency to make hasty responses as they work academic reasoning problems, causing errors in both simple computations and in logic.

5. Activeness in Problem Solving.

The final characteristic of good problem solvers is the tendency to be more active than poor problem solvers when dealing with problem solving. Put simply, they do more things as they deal with a problem. For example, if a written description is hard to follow, good problem solvers may try to create a mental picture of the ideas in order to "see" the situation better. If a presentation is lengthy, confusing, or vague, they try to pin it down in terms of familiar experiences and concrete examples. Furthermore, they will ask themselves questions about the problem, answer the questions, and "talk to themselves" as they try to clarify their thoughts. They may try a flow-chart, brainstorm for possibilities, write on the problem, make diagrams, or use other physical aids to thinking. All in all, good problem solvers are active in many ways which help them get a clearer understanding and how to progress through them.

The Problem Solver's Knowledge Base

Robert Glasser (1984) stated that the knowledge of novice problem solvers is organized around the literal objects explicitly given in a problem statement. Experts' knowledge, on the other hand, is organized around principles and abstractions that subsume these objects. These principles are not apparent in the problem statement but derive from knowledge about the things in the problem or the subject matter associated with the problem. Knowledge of dietetics is needed to solve problems of

nutrition, knowledge of auto mechanics is needed to fix a car, and so on. The problem-solving difficulty of novices can be attributed largely to the inadequacies of their knowledge bases and not necessarily to limitations in their processing capabilities, such as the inability to use problem-solving strategies. "Current studies of high levels of competence support the recommendation that a significant focus for understanding expert thinking and problem solving and its development is investigation of the characteristics and influence of organized knowledge structures that are required over long periods of time" (p. 99).

For example, the authors have experienced for many years the difficulty even gifted students have in solving time-rate-distance problems. We believe the difficulty centers on students' lack of knowledge of the time-rate-distance characteristics of objects as they move toward and away from each other. For instance, consider the problem:

> Car A starts from a point going East averaging 60 MPH, and at the same time Car B starts West from a point 300 miles away from Car A's starting point and averages 40 MPH. How long will it take for the two cars to meet?

Many students cannot do this problem because they don't know that, when two objects start from rest and move toward each other, when they meet they will have travelled the distance they were apart at the beginning. Thus, the solution to the problem is obtained from $300 = 60t + 40t$ (t is for time). To give meaning to the general strategy for solving such problems, we place two students at opposite ends of the room and tell them the room is 50 feet long. They are to walk toward each other and stop when they meet. After the two students meet, we

ask, "What is the total distance the two students have travelled?" Most of the class now realizes that the answer is 50 feet. They have learned a relationship that can help them solve a whole class of problems. The knowledge learned is general and goes well beyond the specifics of this one problem. Reuven Feuerstein (1980, p. 22) sums it up very well: "It is when cognitive processes become detached from specific tasks that cognitive structures are established. These structures are of a more general nature than the learning of specific tasks and, hence, result in more adaptive behavior by the individual."

Students with a wider knowledge base are better at brainstorming for solutions across a wide range of problems. They are more able to understand and construct analogies, they make more discoveries, they see patterns, and they establish new relationships.

SOME SPECIFIC PROBLEM SOLVING STRATEGIES

There are other strategies that can help people become better problem solvers. The ones to be discussed here are: Thinking aloud, using the trial and error method, working backwards, finding all the possibilities, managing time, logical and critical reasoning, and gathering and analyzing data. We have taught these strategies to students and have witnessed students' growth in becoming confident and skillful problem solvers.

Thinking Aloud

When using this strategy, people say aloud their thoughts while attempting to solve a problem. All mental processing, however, need not be vocalized. For example, it is not reasonable to explain the meaning of every word read for a problem. When a student is unsure of what to do, is confused by an idea, or stops for some time to think about it, then some thinking aloud may be appropriate. When the strategy is used, then students should try to think aloud as much as possible. Expressing thoughts, especially at sections of a problem where difficulties or hesitancy arise, is a good way to avoid skipping steps in reasoning, jumping over important information, or being unaware of the point at which being bogged down occurred.

Thinking aloud while solving problems requires practice. At first, many students find it difficult to vocalize their thoughts as they work problems. But students do get used to expressing in words the steps they take and gain confidence in "talking out" the problem in front of the teacher and other students. We use the technique in full class settings, in small groups, and in one-to-one discussions between student

and teacher. The choice of setting depends on the nature of the problem, the students, and the teacher.

The following illustration was taken from John R. Hayes' book, The Complete Problem Solver (p. 56).

PROBLEM Given Jug A which contains nine quarts; Jug B, 42 quarts; and Jug C, six quarts, how could you measure out 21 quarts?

STUDENT: Uh, the first thing is that half of Jug B is the amount you want.

TEACHER: You're right!

STUDENT: Well, you can't get 21 from just multiplying up Jug A or Jug C.

- You can get 18 and 18 respectively, that's as close as you can get, I guess.
- Um, so I'll try to think of different combinations that might . . . or deficit of the 21 quarts . . . and
- Nine and six are fifteen . . . if you took two nines and two sixes, you'd have thirty, which
- Would leave you . . . and pour them into the container, you'd have a,
- An open space of 12, which means nothing. How about . . . see . . . now I'm
- Trying to think of how close to 42 you can get with the nine and the six quantities.
- Nine times five is 45 . . . six times seven is 42.

TEACHER: You're doing fine!

STUDENT: So you can, uh . . . fill B with C evenly.

- If you were to take . . . 36 . . . um, oh, uh, six times four is 24 . . . and if you, uh,
- What I'm trying to get rid of is, is three quarts there . . .

TEACHER: Good.

STUDENT: So if you were to, um . . . still 24. I was trying to think possibly,

- Some way of . . . the difference between the six and the nine is three quarts.
- I was trying to think of . . . a way to uh . . . oh, how about . . . you put the three, six . . .
- Quart quantity into the 42 bottle, which is 18, then the run off, from
- Pouring a nine into a six which is three and 18 is 21.

TEACHER: Well done!

There is a simpler solution to the problem above, but these students found one good solution by talking it over together. From thinking aloud, our students have learned to listen to each other, to locate breakdowns in reasoning, to learn where the stumbling point is, to realize how different people approach the same problem, and to see more than one solution to the same problem on the blackboard at the same time. Students and teachers are often amazed at how much they can learn from each other by thinking aloud.

Trial and Error

Trial and error is often underestimated as a problem solving strategy, but it can be a key strategy for some problems. In the search

for a solution, trial and error can be applied systematically by simply trying different solutions to see if they work. More often than not, however, the search can be narrowed by taking into account relevant knowledge and, by inference, reducing the number of solutions to be tried. The following example is from Problem Solving in School Mathematics (p. 137).

PROBLEM

Find the smallest prime number greater than 840.

SOLUTION

Systematic trial and error. If the problem is to find the smallest prime number greater than 840, begin with 841 and try each successive number, checking for prime divisors until a prime is found. Try 2, try 3, try 5, and so on. (An algorithm for checking this could be programmed on a programmable calculator.)

Inferential trial and error. Consider the same problem. We know that numbers greater than 840 whose units digits are 0, 2, 4, 5, 6, and 8 cannot be prime and that every third number will be divisible by 3. Thus, the first few numbers to try are 841, 847, 851, 853, 857, and 859. To see if 841 is prime we check to see if one of the primes less or equal to 841 divides 841. If it does, we repeat a similar procedure for the succeeding numbers until we find the smallest prime.

Trial and error can also be advantageous in getting a feel for a problem. Trying out a reasonable guess, even if it does not work, can give valuable information. For example, if trying to find a decimal approximation for the square root of two, one might try 1.5 (1 is too

small because 1 x 1 = 1, and 2 is too big because 2 x 2 = 4). Since 1.5 x 1.5 = 2.25, 1.5 is too big, but that is valuable information because it directs the next attempt to a number between 1 and 1.5. Teachers should encourage students to make reasonable guesses at times and should specify for them the value of what was learned from the trial and error and how the error can narrow the search for a solution.

This same way of thinking about the information gained from an imperfect attempt can be applied to solutions of interpersonal problems. Suppose a father and his daughter are problem solving about the condition of her room, particularly about the dirty clothes on the floor and on the furniture. An idea to try might be a clothes hamper in her room. Both would agree that it is a trial solution to be evaluated, say, in three weeks. If the solution is not the right one, the attempt still will help to clarify the problem and suggest a better solution.

One roadblock to becoming a good problem solver is reluctance to take a risk. Many adults have been conditioned over the years to believe that there is some strategy or way to proceed in solving a problem that they "should" have learned, and if they can't "remember how to do this kind of problem," they simply give up. Teachers are confronted with this attitude frequently when their students complain that "we haven't had this yet." Indeed, there are many specific approaches to problems that can be learned. But good problem solvers are not hampered by the conviction that there is one way to solve a problem. They do not rely on some outside authority, but have confidence in their own ability to generate ideas. Teachers can encourage students to become self-reliant by freeing them to make reasonable guesses and to use trial and error to gain insight into a problem.

Working Backwards

Sometimes it is easier to solve a problem by working backwards rather than attacking the problem head on. Working backwards involves a change in perspective in that the new starting point was the original goal and the original starting point the new goal. Working backwards can be helpful because problems are often easier solved in one direction than another.

As an example, consider the following problem from Moshe Rubenstein's Patterns of Problem Solving (p. 19).

> PROBLEM How many tennis matches of single elimination must be played by 1025 players before a winner is declared?
>
> Most of our students start at the beginning by figuring there would be initially 512 games with one player getting a bye. Next there would be 256 matches with one bye, then 128 (1 bye), 32 (1 bye), 16 (1 bye), 8 (1 bye), 4 (1 bye), 2 (1 bye), 1 (1 bye), finals. The sum of 512, 256, 123 . . . 4, 2, 1, 1 is 1024.
>
> It is much more direct and general to start from the end and view one winner and 1024 losers and note that each loser would play one losing game in a single elimination tournament. So there would be 1024 matches.

This working backwards technique not only yields a solution, it also displays a unique strategy that can be used on many problems. The solution path for this problem is more important than the answer since the path yields a general method for solving such problems--work backwards. The solution is known for any number of N players; that is N-1.

Working backwards has many useful applications. Suppose you are writing a position paper to your boss to convince her to accept a

particularly crucial idea. In thinking about how to draft the paper, you might begin by working backwards and ask yourself, "What kinds of questions would she ask me? What would be her major objections? How do I keep from offending her?" By working backwards, by starting with the goal, a more convincing paper can be written.

Finding All the Possibilities

Another important strategy for problem solving is to have a systematic way of listing all possible outcomes of some occurrence. The system must insure that all possibilities are listed and also that only those possibilities which "make sense" from the structure of the problem are listed. An example of an orderly way to list all possible ways for something to happen or all possible arrangements is shown below. Thinking exercises about drawing marbles from bags are useful for developing orderly ways to exhaust all possibilities and they are generalizable to a large number of actual situations.

EXAMPLE. Suppose there are four marbles in a bag, numbered 1, 2, 3 and 4. What are all the ways to draw out the marbles if, once a marble is drawn, it is not returned to the bag? One orderly way of thinking is to actually make a list with the help of a running conversation with oneself:

"OK. Suppose I happen to take out the 1 first?" 1

"Now, I'll list all the ways if the 2 comes second. (Then later, if the 3 comes second and if the 4 comes second.) So there is 12 followed by 34 and 12 followed by 43. And there is no other way for 1 followed by 2." 1 2

1 2 3 4
1 2 4 3

"Now, what are all the ways for 1 first and 3 second? There is 13 followed by 24 and 13 followed by 42. And there is no other way for 1 first and 3 second."

1 3

1 3 2 4
1 3 4 2

"Finally, what are all the ways for 1 first and 4 second? There is 14 followed by 23 and 14 followed by 32. And there is no other way for 1 followed by 4."

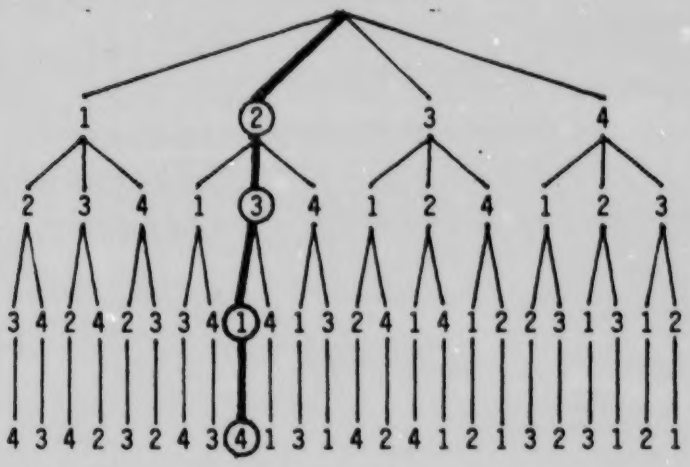
1 4

1 4 2 3
1 4 3 2

A similar conversation goes on with oneself to generate all the arrangements when 2 is drawn first, when 3 is drawn first, and when 4 is drawn first. The results:

2 1 3 4	3 1 2 4	4 1 2 3
2 1 4 3	3 1 4 2	4 1 3 2
2 3 1 4	3 2 1 4	4 2 1 3
2 3 4 1	3 2 1 4	4 2 3 1
2 4 1 3	3 4 1 2	4 3 1 2
2 4 3 1	3 4 2 1	4 3 2 1

So, there are 24 ways to draw four marbles in order if the drawn marble is replaced in the bag. Every possibility is listed and there are no more. Another skill for finding these 24 possible ways is to draw a "tree:"



4 choices for 1st marble

3 choices for 2nd marble (so far 4 x 3 or 12)

2 choices for 3rd marble (so far 4 x 3 x 2 or 24)

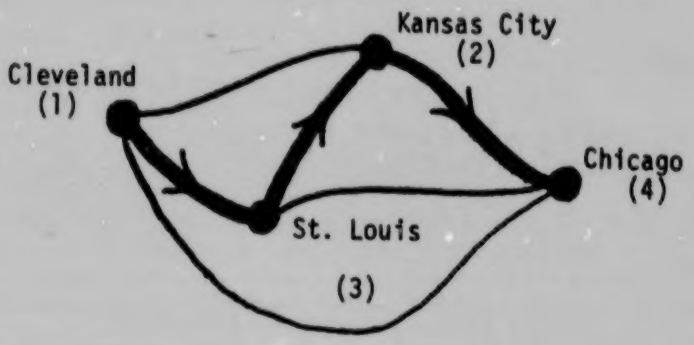
1 choice for 4th marble (4 x 3 x 2 x 1 or 24)

There are 24 "paths" down this "tree" and the one that is indicated above represents the combination 2 3 1 4.

The skill of drawing a tree to determine all possibilities is an important one. Suppose all the possible ways to arrange 10 digits (without replacement as in the example above) were critical information for the solution to a problem. Listing all the possibilities would be formidable and the tree would be impractical to draw. But by reducing the problem to a simpler problem (another problem solving strategy) one could realize that there is a pattern for finding the number of combinations. The tree for the 4-digit problem makes it clear that there are 4 x 3 x 2 x 1 or 24 ways to arrange four digits. So it is logically sound to compute 10 x 9 x 8 x 7 x 6 x 5 x 4 x 3 x 2 x 1 to find the number of ways to arrange 10 digits (without replacement).

This kind of thinking is a useful problem solving skill. The 4-digit problem has the same structure as figuring out, for example:

- How many different ways can 4 colors be used to paint a car if the colors for the body, the top, and two parts of the trim are arranged differently? (24 ways)
- What is the probability of drawing a "winning number" 2 1 4 3 from a box containing four chips labelled "1," "2," "3," and "4?" (1/24 or 1 of the 24 possibilities).
- How many different routes are there which reach all of 4 cities only once and which could originate in any of the four cities? (24) One such route, (1) Cleveland to (3) St. Louis to (2) Kansas City to (4) Chicago, is shown below. The illustration shows that regardless of the city of origin, any other city can be reached next, making this situation analagous to the 4-digit problem.



Very often, the number of ways to do something or the likelihood of an event occurring is important information for solving a problem, not only in mathematics, but also in other situations. It is a skill that can and should be taught as one of many problem solving strategies.

Time Management

Time management can influence problem solving. Poor scheduling can lead to insufficient time to work through a solution to a problem, or perhaps to never even getting to the problem. Problems can be solved only by taking time to solve them. An appropriate amount of time must be allocated for reflecting on the problem, for considering different ways to approach a solution, and for reviewing and critiquing the steps used. The pressure that can result from poor scheduling can cause subpar problem solving by limiting the amount of planning time and the time needed for patient deliberation. A student's patience and perseverance is often a key to good problem solving. A necessary condition for this is good time management skills.

We have recommended to students that they keep a chart of their activities to use as a basis for managing their time better. Time priorities often have to be set each day and a chart or list can help. Some students do not manage their time well enough to acquire an

essential piece of knowledge, get to the library, or talk to someone who can help them. Allocating specific blocks of time to specific tasks according to their importance and the time they require is a useful skill. Systematic reflection on one's use of time and on how much is lost if it is used inefficiently can lead students to modify their own behavior.

Time management requires scheduling, but flexibility in following a schedule is also important. For example, there is a problem solving strategy which is useful when one has come to a dead end or exhausted all ideas for approaching a problem. Wickelgren (1974) calls the strategy "incubation" and it means simply to get away from the problem for a while. It is a common experience to "sleep on a problem" and to solve it with a new insight the next day. Even when time is limited, as in taking an exam, going on to other problems and then coming back can be useful. Teachers can model this strategy from time to time by leaving problems with students instead of rushing to solve them before the bell rings.

The key to time management, then, is to recognize the need for time to gather information, to try different ideas, to critique solutions, and also to have the flexibility in one's schedule for some incubation time.

Logical and Critical Reasoning

A lack of logical and critical reasoning skills hinders students' progress in becoming adept problem solvers. The more we listen to students talk aloud about their problem solving, check their papers, and observe their activities, the more we are impressed with the extent of their deficiencies in logical and critical reasoning.

One of the major problems students have is dealing with ambiguities in the English language. For example, consider the real-life story of a famous mathematician who had to take a driving examination. He had memorized many statements from a booklet, including the following:

It is illegal to park within 15 feet of a fire hydrant.

As part of the test, he was given some "true-false" questions, one of which was:

It is illegal to park within 9 feet of a fire hydrant. False __ True __

The mathematician checked "true" on the grounds that if the statement he had memorized was true, then the question in the test was true. The examiner, however, claimed that the correct response was "False," since the statement in the booklet explicitly mentioned "15 feet" and not "9 feet." The mathematician was correct, according to the rules of logic.

Next consider the phrase from the song "Home on the Range:"

". . . and the skies are not cloudy all day."

What on earth does it mean? Does it mean that all day long there is <u>never</u> a cloud in the sky? Does it mean that the skies are not cloudy <u>all</u> day long--there is usually a moment, about 2:15 p.m. or so, when a bit of sunshine and blue sky breaks through? Just what does it mean? Does it mean that, on the average, the skies are much less cloudy than they were back East? Who knows?

As another example of ambiguity in the English language, consider the two statements:

a) A Swede invented dynamite.

b) A Swede is a European.

The meaning of the indefinite article "A" before "Swede" in these two statements is quite different: In (a) it means one; in (b) it means every.

The phrase ". . . and the clouds are not cloudy all day" was, of course, never intended to be a precise statement about anything. It was intended merely to evoke an image of the clear, bright, sunny West. But even when one tries to be precise, the ambiguities of English can present problems for students.

As an illustration of the role of logical reasoning in problem solving, the following table was given to a class of high school seniors.

Resting Systolic Blood Pressures Found in 20 Patients

Morning Patients (Doctor I)				Afternoon Patients (Doctor II)			
Patient Number	Sex	Age	Pressure (mm Hg)	Patient Number	Sex	Age	Pressure (mm Hg)
1	F	25	120	11	F	22	122
2	M	42	150	12	F	47	151
3	F	22	120	13	M	21	118
4	F	35	135	14	F	40	133
5	F	45	145	15	F	44	141
6	F	31	125	16	F	19	126
7	F	21	120	17	F	25	120
8	F	27	130	18	M	22	128
9	F	32	130	19	F	39	133
10	F	20	120	20	F	21	123

Accompanying the table was the statement:

If a patient had both a morning and an afternoon blood pressure reading taken, then the afternoon reading would be higher.

Students were to select one of the following as their answer:

(A) The statement is supported by the information given.

(B) The statement is contradicted by the information given.

(C) The statement is neither supported nor contradicted by the information given.

Every student in the class of 12 pupils marked "B" because they said that no patient had a morning and afternoon reading. This is an incorrect interpretation of the hypothetical "If . . . then . . ." statement. The correct answer is "C" since no consistent pattern exists of higher readings in the afternoon for individual patients. Who knows what data collected on the same patients in both morning and afternoon would show?

This same class also declared these next two open sentences to be equivalent:

(1) $x(x-3)=0$

(2) $x=0$ and $x=3$

They are not equivalent. In statement (1), x cannot be replaced by both 0 and 3 at the same time. However, the two sentences would be equivalent if the word "and" were replaced by "or."

Students need to be given more practice and guidance in dealing with the logic of problems with a particular emphasis on teachers giving them many sound and appropriate problems to work and listening to them reason aloud. We strongly recommend An Introduction to Logic by Exner and Kaufman (1978) from CEMREL, Inc., St. Louis, Missouri.

Critical reasoning is another area of student deficiencies. Students often lack skills to assess expressed ideas, beliefs and statements which one encounters daily through the media and through remarks made by people in the form of opinions, reports, rumors, etc. There is quite a well-organized body of knowledge on critical reasoning.

The process of critical inquiry is an impartial one. Judgments and evaluations are delayed until the data is in. Observations, people's opinions, collected information, etc., should all be in before decisions are made. The process is to be objective, avoiding preconceived versions of the results. The problem solver should be open to inviting further inquiry if people are not satisfied or problems are not resolved. Also, in critical inquiry people's feelings are often involved. Respect for people's personal dignity must be remembered when people are the objects of the inquiry.

Another important part of critical inquiry is evaluating the assumptions being made during the inquiry. If assumptions are not clearly in mind, then invalid conclusions can be drawn, inappropriate decisions made, or people's feelings hurt. An example from Joan Hearn's (1982) More Life Skills is:

> Willie Jones is a fifteen year old, Grade 10 student who spent Saturday night breaking windows at his high school.
>
> His mother's assumption is that he is a crazy, mixed-up kid.
>
> His father's assumption is that boys will be boys.
>
> His principal's assumption is that there are too many boys like Willie about and that the school is better off without them.
>
> The police's assumptions are that public property must be protected and wrong doers must be discouraged.

It is clear that if Willie's mother were to discuss Willie's activities with his high school principal, neither of them would get anywhere because they would be arguing from different assumptions.

People can improve their critical reasoning skills. And it is evident from our experience that there is no substitute for practice. Students must be given good situations, problems, and simulations from which to develop and sharpen their skills. An excellent source is Joan Hearn's (1982) More Life Skills.

Gathering, Recording and Analyzing Data

The first step in the Problem Solving model is to understand the problem. When full information is presented to a student, understanding the problem involves careful reading, eliminating extraneous information, and for some problems, drawing a sketch or a diagram or organizing given data in a table. These are the usual kinds of problems students are given in school. Unfortunately, most problems encountered in one's life (at work, at home, or socially) are not so "neat." Crucial or helpful information is often missing and the problem solver must have skills not only for obtaining necessary information, but also for recognizing what information is needed. Some examples of such problems follow.

- How can productivity be increased in Plant A?
- How can the absentee rate be reduced?
- What is the least expensive way to get Job X done, considering labor costs, cost of materials and employee morale?
- How do I get my car started so I can get to work on time this morning?
- What steps can I take to effect a behavior change in Person Y?
- To cut costs and maintain sales volume, where can money best be saved in the production of Product X, packaging or advertising?
- What is the best solution for a problem involving a disagreement between labor and management?

- How can the quality of on-the-job training be improved to teach skills more efficiently?
- What are the important variables for increasing morale?
- How can I plan my finances to reserve X amount of money per month for investments?

Data-gathering can occur on many levels. In some cases, unstructured observation is useful. For example, simply watching a production line for an hour could help a person to generate ideas for a more structured efficiency study. Or a task-oriented group could be observed for clues about group discord. More analytical data-gathering involves the use of checklists or coding of events or behaviors. Once data is collected, a second skill is to summarize the information in a meaningful form. If the information is quantitative, data from a checklist can be recorded in a variety of kinds of graphs, tables, or figures. Non-quantitative observation can be categorized or written up as a case study. The skill of selecting a way to represent data interacts with a third skill: Analyzing observational results.

General Motors recognizes that data-gathering is often critical for problem-solving. The manual they use for training employees to conduct Employee Participation Groups includes the following data-gathering skills:

1. Making Check Lists. The following examples from the GM manual show how information can be organized about two different aspects of possible causes of a parts shortage (e.g., type of part and number of shortages by month). Direct observations are recorded as they occur.

Type Of Part	Number Of Shortages By Month												
	J	F	M	A	M	J	J	A	S	O	N	D	Total
001	✓												
002	✓✓												
003													
004													
005													
006													
Other													
Unknown													
Total													

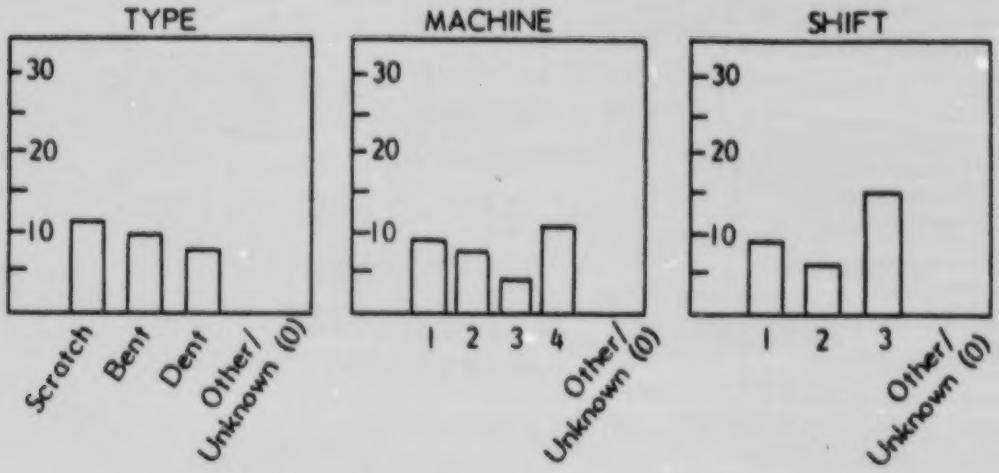
Type Of Part	Number Of Shortages By Shift				
	1	2	3	Other	Total
001	✓				
002		✓	✓		
003					
004					
005					
006					
Other					
Unknown					
Total					

Type Of Part	Length Of Shortage				
	1 Hr.	1 Wk.	1 Mo.	Other	Total
001		✓			
002	✓		✓		
003					
004					
005					
006					
Other					
Unknown					
Total					

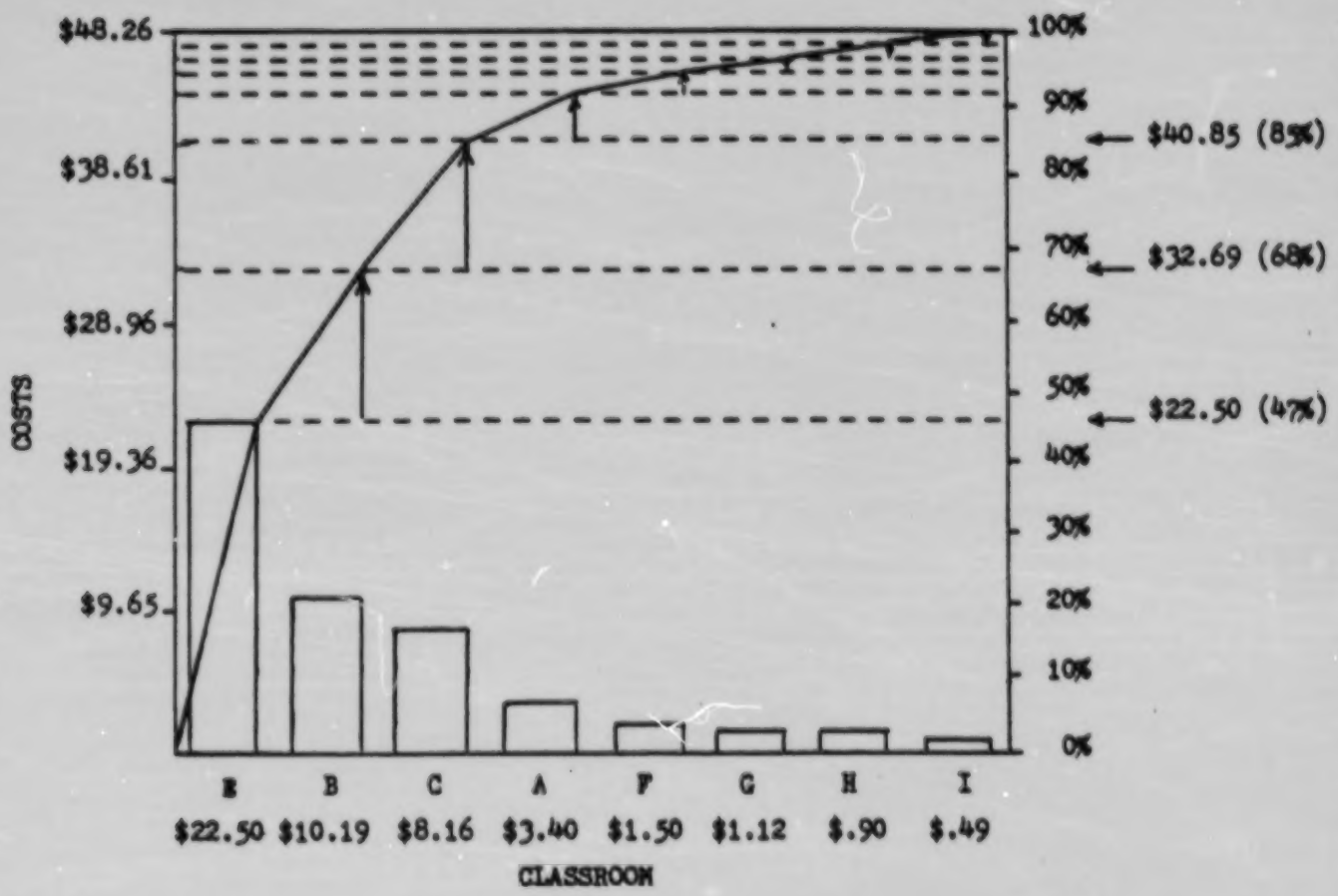
2. Making Charts. Information from check lists can be recorded in charts which help the problem-solver to analyze the problem to be solved. An example:

Type Of Reject	Machine				Total
	1	2	3	4	
Scratch	4	2	1	5	12
Bent	3	1	2	4	10
Dented	1	4	1	2	8
Other/Unknown	0	0	0	0	0
Total	8	7	4	11	30

A second kind of chart is a bar graph. The following graphs indicate that possible causes of rejects to consider first might be (1) something making scratches (12 of the 30 rejects); (2) involved with the 4th machine (11 of the 30 rejects); (3) on the 3rd shift (15 of the 30 rejects).



A third kind of chart is a Pareto chart. Pareto charts organize vital information and data in a cumulative way. In the following example from Lloyd and Rehg (1983), the weekly cost of supplies for eight classrooms has been converted into percentages which have been depicted in a bar graph with the percentages in descending order. The solid line illustrates cumulative percentages. In this example, the graph shows that classrooms E and B are responsible for 68 percent of the total expenditure. One option from this data is to conclude that the other classroom expenditures are "trivial" factors and attention should be focused on the costs for schools E and B.



Social and interpersonal problem solving can also require data-gathering. Much of this must be done via observation of people and their interactions. In conflicts between two people, the needs of both people must be known and good listening skills (to be discussed in a later section) can provide much of the necessary data. For example, if an employee gradually becomes less productive and less cooperative, a supervisor's listening skills might reveal problems ranging from poor health to financial problems to unsatisfactory working conditions. Such information-gathering is critical for interpersonal problem-solving.

Many interpersonal problems involve needs, preferences, or values of groups of people. Useful information can be collected via interest

surveys, evaluation forms, or other questionnaires. One of the most effective ways to improve the quality of training programs is to conduct frequent anonymous evaluations by participants. Tallies of responses to objective items often reveal patterns of possible causes of problems. For example, ratings for the instructor's rapport with the class might be low while ratings for instructional materials are high. Open-ended questions are extremely useful and usually give additional relevant information.

Objective observation of group dynamics is often the key to solving problems involving group cohesiveness and group productivity. In most groups, people assume roles (leader, follower, antagonist, peace-maker, clown, etc.). Observation of interactions among members of a group is useful information for a group facilitator.

Good and Brophy (1978) give many examples of instruments for gathering information about classroom dynamics and teacher behavior. The following form, for example, can be used to determine whether a teacher is giving appropriate feedback to students about the adequacy of their responses in discussion and recitation sessions.

TEACHER FEEDBACK WHEN STUDENT FAILS TO ANSWER CORRECTLY

DIRECTIONS: When a student is unable to answer a question or gives answers incorrectly, code as many categories as apply to the teacher's feedback responses.

BEHAVIOR CATEGORIES

1. Criticizes
2. Says "No," "That's not right," ect.
3. No feedback--goes on to something else
4. Ambiguous--doesn't indicate whether or not answer is acceptable
5. Asks a student or the class whether answer is correct
6. Asks someone else to answer the question
7. Repeats question to same student, prompts ("Well?" "Do you know?" etc.)
8. Gives a clue or rephrases question to make it easier
9. Asks same student an entirely new question
10. Answers question for the student
11. Answers question and also gives explanation or rationale for answer
12. Gives explanation or rationale for why student's answer was not correct
13. Praises student for good attempt or guess
14. Other (specify)

1. 2	13. ____	
2. 2,6	14. ____	
3. 2,8	15. ____	
4. 2,10	16. ____	
5. 2,12	17. ____	
6. ____	18. ____	
7. ____	19. ____	
8. ____	20. ____	
9. ____	21. ____	
10. ____	22. ____	
11. ____	23. ____	
12. ____	24. ____	

If instruction in problem solving is to be transferable to real-life problems, students must learn to gather relevant information and they must be armed with tools for recording and analyzing their observations.

THE FIVE STEP MODEL EXTENDED FOR PROBLEM SOLVING

The Five Step Model has been developed as an aide for students in solving problems. It is extended here to show how many useful strategies can be embedded within the model.

Extended Model

1. Understand the problem
   - What are the essential data?
   - Is there enough information to solve the problem?
   - Would a figure or sketch help? Maybe introduce symbols or other variables.
   - Separate the problem into manageable parts, if needed. Write down each part.
   - Can the problem be restated in a different way to help understand it?
2. Brainstorm for Possible Solution Strategies
   - Generate a lot of ideas. Don't judge them, just write them down.
   - Has a problem like it been solved before?
   - Would working a related problem be useful?
   - If there were some particular additional information, could the problem be solved? Where would the information be obtained?
3. Choose a Tentative Solution Strategy
   - Remember, the strategy may not work and the process may have to be started over.

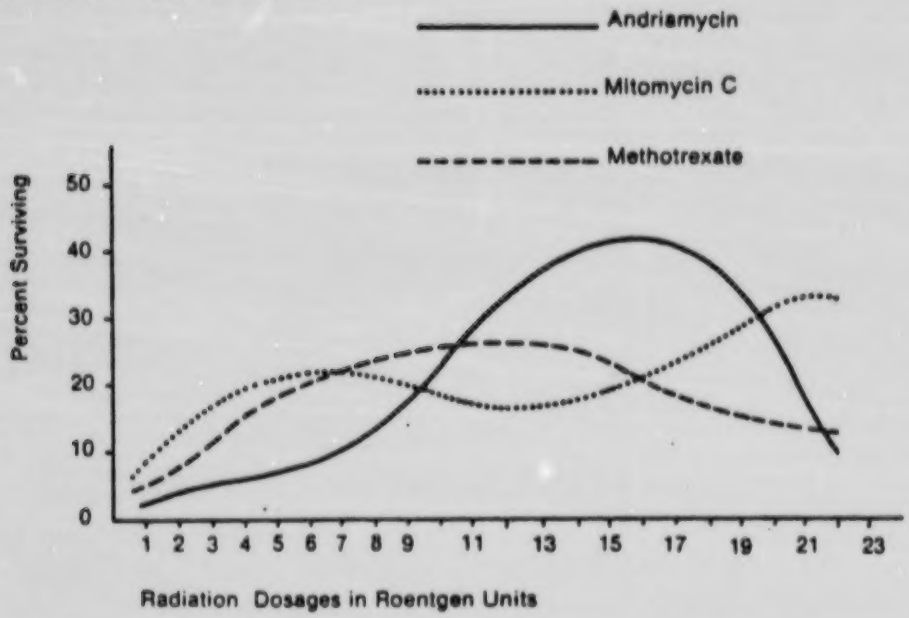
- For "people" problems, consequences associated with carrying out tentative strategies must be carefully weighed.
- Also, if people are working out an interpersonal problem, then the tentative strategy will likely be a compromise. No one is likely to get everything they want.

4. Carry Out the Tentative Solution Strategy
   - Check each step as the plan is carried out. Check that each step is OK. Is each step correct or valid?
   - Are there probably places for errors, mistakes, or faulty reasoning? Where are they?
   - Would it be useful to have someone else go over your steps?
   - For implementing solutions to "people" problems, decide "Who does What, When." Maybe write it down.
5. Learn
   - Check the result if possible. Is the judgment sound? Does it have a reasonable chance of solving the problem?
   - What are the implications or consequences of the solution?
   - Could the problem be worked another way? Perhaps look at other people's solutions and hear what they have to say.
   - If appropriate, evaluate the effectiveness of the solution.
   - Have enough problems like this one been worked to begin to generalize to a plan for solving similar problems?
   - Does this solved problem open up new relationships that hadn't been thought of before? Think about it!
   - What are your strengths as a problem solver? Your weaknesses?
   - Are you getting involved in solving problems? Are you doing the work or is someone else? Your involvement is essential.

Problems follow that students have solved using the extended model.

Example 1. One useful strategy for this problem is to break it into two parts: The two parts are separated by "AND." The problem, as it is given to students, does not have the word capitalized. An additional strategy some students have used is to use colored pens to color code appropriate parts of the graph so that they have visual cueing of what is being asked for in the problem.

PROBLEM. The graph below shows the percentage of lung cancer patients surviving longer than five years after receiving six weeks of radiation therapy in indicated dosage along with indicated chemotherapeutic agent.



What is the dosage for which Adriamycin has a higher five-year survival percentage than does Mitomycin C and a lower five-year survival percentage than does Methotrexate?

EXAMPLE 2. For this next problem, many students use a sketch to help solve it.

PROBLEM. Two athletes race around an oval track 440 yards long. One races at ten yards per second and the other at eight yards per second. How much time is required for the faster person to gain one lap?

EXAMPLE 3. This problem illustrates how useful a drawing or sketch can be for keeping track of progress through a problem. It also illustrates how introducing symbols or notation (Pup X, Pup Y) can be a worthwhile strategy. The drawing under the problem was used by one of our students.

PROBLEM. Peter owned a St. Bernard and two pups. He bought 100 pounds of dog food. The mother ate ten pounds per day and each pup ate two pounds per day. After three days one pup was sold and after seven days the other was sold. How long did the dog food last?

Day	1	2	3	4	5	6	7	8
Mother	10	10	10	10	10	10	10	10
Pup X	2	2	2	2	2	2	2	
Pup Y	2	2	2					
Cumulative Total:	14	28	42	54	66	78	90	100

Answer: 8 days

EXAMPLE 4. Some students have difficulty solving this next problem until they work an easier problem like it. A video tape we have of students "talking aloud" to help solve problems has this on it from one student: "Well, let's see--if I drove to St. Louis and back in ten hours, I would just divide the total distance by ten to see how fast I

went. So, for this problem, one way is 300, round trip is 600, total time is 12 hours--so the answer is 600 divided by 12. Right?"

PROBLEM. If a car travels five hours at 60 mph and returns over the same path in seven hours, find the average speed.

EXAMPLE 5. Recently we had a student who couldn't find what part 1/2 is of 5/6. STUDENT: I can't do this problem! TEACHER: Do you know what part seven is of nine? STUDENT: Sure, seventh-ninths, seven divided by nine. TEACHER: Can you do the original problem now? STUDENT: I've got it, 1/2 divided by 5/6. TEACHER: Yes, good for you!

EXAMPLE 6. The following problem requires very careful reading and understanding of the data given in the table. Nothing can be omitted or just skimmed over. Also, there is some superfluous information (where?). The problem statement itself takes a skilled reader to not make a mistake or a misinterpretation. It is also useful to analyze this problem in two parts (Hospital B and Hospital C).

PROBLEM. The table gives the duration of stays by patients in Midvalle's Memorial Hospitals.

Hospital	No. of Entering Patients Staying Longer Than 5 Days	% of Entering Patients Staying Longer than 5 Days	% of Entering Patients Staying Longer than 1 Week
A	53	14	10
B	42	17	8
C	60	20	12
D	75	25	14
E	80	33	20

It is true that the percentage of patients staying longer than five days at Hospital C who stay longer than one week is greater than

the percentage of patients staying longer than five days at Hospital B who stay longer than one week? (Answer: Compare 8/17 and 12/20).

EXAMPLE 7. This final problem combines two very useful strategies for solving problems: Trial and error, and a systematic way of listing all possibilities.

PROBLEM. Used kickballs cost $2.00, volleyballs cost $4.00, and basketballs cost $5.00. A combination of six balls where there must be at least one of each kind could not cost which one of the following? Show a combination of balls for each of the other three costs.

A. $18.00
B. $25.00
C. $23.00
D. $26.00

HIGHER ORDER PROBLEM SOLVING SKILLS

Since its inception in 1969, the National Assessment of Educational Progress (NAEP) has surveyed the knowledge, skills, and attitudes of over one million students. The Education Commission of States, which collects this data, reported that "today's minimum skills are demonstrated successfully by a majority of students. Higher order skills, however, are achieved only by a minority of 17-year-olds, and this proportion declined over the last decade. If this trend continues, as many as two million students may graduate in 1990 without the skills necessary for employment in tomorrow's marketplace" (Education Commission of the States, 1982, p. 2). They further noted that:

> The "basics" of tomorrow are the skills considered to be of a higher level today. These skills include:
>
> - Evaluation and analysis skills
> - Critical thinking
> - Problem-solving strategies (including mathematical problem-solving)
> - Organization and reference skills
> - Synthesis
> - Application
> - Creativity
> - Decision-making given incomplete information
> - Communication skills through a variety of modes (p. 6)

A survey of 123 school systems (Henry & Raymond, 1982) found that the basic skill of "reasoning" had the smallest percentage of school systems evaluating students as having superior preparation. Sixteen percent of the schools acknowledged that "the majority of work force-bound students were inadequately prepared to reason through complex problems and decisions" (p. 121).

Archie E. Lapointe, Executive Director of the Center for the Assessment of Education Progress, drew the following conclusion from NAEP findings (1984).

> Closer examination of the data reveals that poorly developed problem solving skills hinder students' performance in mathematics. Indeed, weaknesses exist in the so-called higher-order skills in general. Most students do well with literal comprehension but lack the skills of inference, analysis, and interpretation. Today's definition of functional literacy calls for these higher-order skills more than ever before, even as students' mastery of them is seemingly on the decline. Clearly, a renewed focus on these skills is needed. (p. 666)

As students attempt to solve more and more complex problems, the need for them to acquire higher-order problem solving skills increases. For General Motors, some of these skills are problem analysis, decision-making, and planning. Some higher-order skills listed by Piaget (1952) are hypothetical thinking, observing and discovering patterns, establishing relationships, making generalizations, and sophistication with combinatorial and probabilistic thinking. Bloom's (1956) hierarchy of

cognitive skills, described next, begins with knowledge of facts and extends to higher-order skills.

Level 1: Knowledge. The ability to recall specific facts, methods, or procedures: Terminology, facts, rules, trends, classification schemes, criteria, methodology, principles, generalizations, theories, structures. This level involves little more than retrieving stored information.

Level 2: Comprehension. The ability to make use of what is being communicated: To translate or put information in another form (restate an idea, interpret a diagram, summarize, draw a picture); to interpret or reorder ideas and comprehend relationships; to extrapolate or go beyond the given data (drawing conclusions, theorizing, predicting). This level involves understanding ideas.

Level 3: Application. The ability to apply knowledge and principles to actual situations: Generalizing to another situation. This level involves putting into action knowledge which from Level 2 has been understood.

Level 4: Analysis. The ability to classify or break material down into its components, to understand the relationships between the components, and to recognize the principle that organizes the structure or the system: To compare and contrast, to distinguish between fact and opinion, to recognize extraneous information, to recognize unstated assumptions, to compare theories. This level involves a kind of logical thinking similar to Piaget's formal operations.

Level 5: Synthesis. The ability to bring together ideas and knowledge from many sources to form new ideas, methods, or procedures: Unique communication, a plan, a set of operations, a strategy. This level involves creative or original thinking.

Level 6: Evaluation. The ability to make quantitative and qualitative judgments: To weigh, to examine, to analyze, to use criteria, to recognize the best of several reasonably good answers or solutions. This level requires the abilities of the first five levels and is crucial for substantive problem solving.

Although Bloom et al. prepared their widely accepted taxonomy in 1956 as a guide for developing and evaluating education objectives, actual classroom instruction has generally focused on Level 1 and Level 2 objectives. Bloom (1984) observed:

> . . . teachers in the United States typically make use of textbooks that rarely pose real problems. These textbooks emphasize specific content to be remembered and give students little opportunity to discover underlying concepts and principles and even less opportunity to attack real problems in the environments in which they live. The teacher-made tests (and standardized tests) are largely tests of remembered information. After the sale of over one million copies of The Taxonomy of Educational Objectives--Cognitive Domain (1956) and over a quarter of a century of the use of this domain in preservice and in-service teacher training, it is estimated that over 90% of test questions that U.S. public school students are now expected to answer deal with little

> more than information. Our instructional material, our classroom teaching methods, and our testing methods rarely rise above the lowest category of the Taxonomy--knowledge. (p. 13)

Bloom was able to cite examples of successful attempts to teach higher-order skills and he emphasized the importance of such skills for problem solving and coping with change.

> Although there is much of rote learning in schools through the world, in some of the national curriculum centers (e.g., Israel, Malaysia, South Korea) I find great emphasis on problem solving, application or principles, analytical skills, and creativity. Such higher mental processes are emphasized because these centers believe that they enable the student to relate his or her learning to the many problems he or she encounters in day-to-day living. These abilities are also stressed because they are retained and used long after the individual has forgotten the detailed specifics of the subject matter taught in the schools. These abilities are regarded as one set of essential characteristics needed to continue learning and to cope with a rapidly changing world. (p. 13)

There is no better context within which to develop higher-order skills than the context of problem solving. A bonus is that the lower cognitive levels of knowledge and understanding can also be developed via problem solving. The National Council of Teachers of Mathematics in its Agenda for Action--Recommendations for the 80's (1980) had as its

number one recommendation that mathematical content for K-12 be taught primarily in a problem-solving context.

Below, we will illustrate the need for higher-order problem solving skills for complex problems by relating an adult problem-solving session in which a problem from the General Motors manual was attacked.

THE PROBLEM: Your company has just obtained a one-year contract for delivering six truck loads of hazardous materials a month. All six trucks are enroute, and this is the first time any one of you has driven this busy road. All trucks are identical though they are loaded different. You will make 11 more deliveries this year.

The second truck is immediately behind the first truck, which is pulling a forklift. Four other trucks are about 15 minutes behind on the same road. The first truck went under a concrete underpass with no problem, but the second truck got stuck. Comparing the shipping documents you realize the first truck is carrying 400 containers weighing 50 pounds each. The second truck carries 300 larger containers that only weigh 40 pounds each. The cargo is on pallets. There is an open truck service station ahead. It has a fully equipped wrecker for servicing trucks on the highway. All the trucks must arrive at the destination 20 miles ahead within one hour or your company will have to pay penalties. There is an alternate route behind you but it is 10 miles longer with equally heavy traffic. You are members of the crew driving the stuck truck. What will you do?

The problem-solving group first agreed on a statement of their problem: How to get unstuck and arrive at the destination on time without hurting anyone. They they looked for the cause of the problem. They assumed that they had checked for causes such as something wedged on top of the truck or mechanical failure and had found none. The problem was needing only about an inch more clearance since the truck did not collide with the underpass, but got stuck under it. They agreed that, since all trucks were identical, the lighter load of the second truck (12,000 pounds) as compared to the first truck (20,000 pounds) was the cause. The first truck had more clearance. Then they examined the resources at hand: The forklift on the first truck, a C. B. radio, $50 petty cash, the usual truck equipment (truck jack, tire tool, flares, reflectors, etc.), and the highway-class truck wrecker at the truck service station ahead. (THE GROUP WAS USING THE SKILL OF ANALYSIS IN CLARIFYING AND UNDERSTANDING THE PROBLEM.)

The group decided it was ready to brainstorm for solutions. They agreed that everyone would contribute and no ideas would be criticized or discussed during the brainstorming. The following list of possible solutions was generated.

1. Call the first truck on the C. B. Get Highway Patrol help to position the first truck behind the second truck and, using the forklift, transfer some of the load from truck 1 to truck 2.
2. Call the first truck on the C. B. The first truck would stop at the truck service station, transfer the forklift to the truck wrecker, sent it back to wait for truck 3 and load some of its cargo on truck 2.

3. Let enough air out of the tires of truck 2 to lower it one inch.

(HERE, THE GROUP WAS USING THE SKILL OF SYNTHESIS, BRINGING KNOWLEDGE TOGETHER TO ORIGINATE A STRATEGY OR PLAN.)

The group felt that it was ready to analyze the possible solution strategies. During this time, they frequently reminded each other of the problem statement and they also considered expense to the company for the immediate solution, the risk of losing the contract or paying a penalty, and the safety factor for the truck's crew. They rejected solution 1 because of the traffic hazards and possibility that truck 1 would then not make it through with less weight. Even though solution 2 would involve hiring the wrecker, it was a solution they could count on, and paying a penalty or losing the contract was financially very bad for the company. The traffic hazards still bothered them. Solution 3 was their preference for the simplicity and the time factor, but it had to be tried to see if enough air could be let out of their tires to lower the truck one inch. They finally came up with a plan which incorporated ideas 2 and 3:

1. Call ahead to truck 1, informing them of the problem and that truck 2 would attempt the solution of letting air out of the tires. Tell truck 1 to stop at the service station ahead and prepare to transfer the forklift to the wrecker.
2. Attempt to get unstuck by letting air out of the tires. If it works, inform truck 1 and call the other four trucks giving them full information about the problem they might face, the load weights involved, and the solution for truck 2. Check the

possibility that the alternate route might be feasible for them.

3. If deflating the tires doesn't work, call the service station and the Highway Patrol and arrange to load some cargo from truck 3 to truck 2 by forklift. Have the wrecker stand by at the underpass for possible problems with the other trucks.

Once the immediate strategy was determined, the group returned its attention to the long-range problem of the remaining 11 deliveries. They recommended to the company that loads be computed or the height of the trucks measured to prevent further difficulties. (HERE, THE GROUP WAS GENERALIZING A SOLUTION BASED UPON THE ONE APPLIED SOLUTION, FURTHER ANALYSIS AND SYNTHESIS.)

Problems such as this, and problems with much more complexity, are now being solved by workers. Higher order problem solving skills are "basic" for these problems, and they must be considered "basic" in pretechnical curricula. Two kinds of opportunities for complex problem solving are available for students before they enter the workforce. One is solving problems that arise naturally in the school setting. Another is solving problems provided in simulated settings.

Simulations

In simulations, students are actively involved. The student assumes an active role as a problem solver and often controls decisions and consequences that are a part of most problem solving situations. For example, in the simulation Life-Career (published by Western Publishing Co.), students must make decisions and solve problems for a fictitious person as the person deals with work, marriage, and education. Players

plan time and activities relative to school, studying, job, leisure time, and family. The game generates a universe of simulated experience that students can compare with the real world; that is, they can compare the experiences in the game to what they believe about their own world. Sarane Boocock (1968) found that the Life Career simulation increased students' factual knowledge about careers; established new relationships for students on how jobs, school, and family can be very interdependent; helped students learn that there is a causal relationship between their behavior and the outcome of events; and increased student confidence in their decision making and problem solving abilities.

The World Future Society published a directory of information resources which includes descriptions and references for 45 simulation games (Cornish, 1979, pp. 627-638). Some other resources:

- Simulation Games for the Social Studies Classroom by William A. Nesbitt (1971), Foreign Policy Association, Glenview, IL.
- Construction and Use of Written Simulations by Christine McGuire, Lawrence Solomon, and Philip Bashook (1976), The Psychological Corporation.
- Simulation Games in Learning by Sarane Boocock and E. O. Schild (1968), Sage Publications, Beverly Hills, CA.

Good simulations require most of the essential moves of successful problem solvers: Gathering data, selecting alternatives, conducting analyses, synthesizing, generalizing, making decisions, planning, and taking action. According to William A. Nesbitt (1971), simulations teach students to think critically, examine alternative strategies, and to critique their own decisions and behaviors. Simulations provide an

opportunity for students to solve substantive problems and to gain confidence in their abilities to tackle problems, wrestle with them, and by progressing a bit at a time, eventually solve them. An example of a simulation for solving office-related problems follows.

You are a member of an office staff for a company whose president made a decision to trade in all the existing office equipment and replace it with a system of equipment from one company. The office staff was asked for input on such matters as new procedures, workflow, job responsibility, training for use of new equipment, and guidelines for implementing the new procedures. Nevertheless, after working in the new setting for six weeks, some problems have arisen with job satisfaction and the staff is meeting to search for solutions. You are one of the following staff members.

· Sandara Miles was Mr. Hamblin's secretary. Her duties were to keep his calendar, take his calls and serve as receptionist for his callers, process all his paperwork and retrieve information from his files. Her new title is "office manager." She is now responsible for directing the work flow from all the executives. Since there was no cross-training, she is unable to retrieve information when Don, the information processor, is gone. Sandra also supervises all the work of the office staff. She is beginning to feel that she lacks supervisory skills. She is also frustrated about the pressure to resolve problems which have arisen with the rest of the staff, and that is the reason she has called this meeting.

· Don Fieldman was Mrs. Logan's secretary. His duties were similar to Sandra's. Don's new title is "information processor." He was eager to be trained on the new equipment and is enjoying the

challenge of problem solving for what the equipment could do for his work load. But Don is having problems with his back and his eyes. He complains of the glare on the screen. In addition, his equipment was placed in a small room adjacent to the main office and he misses the contact with the rest of the staff.

Charlene Henry was moved from her job as clerk/typist to that of receptionist. She takes all incoming calls on the switchboard and receives clients. She is having difficulty with retrieving information for customers and dealing with their irritation when they feel that they are being slighted.

Mason Tyler was the clerk/typist who was primarily responsible for the filing system. His new position is "records clerk" and he has full responsibility for storage and retrieval of records. Like Don, he misses contact with the rest of the staff, but also is running into problems with the increased flow of paper resulting from the new system. Another problem is that no system has been identified for filing information stored on disks. Mason feels pressured to respond efficiently to requests for information.

Your staff meeting has begun, and the entire staff has agreed that the office environment is "depressing" and that these unresolved problems are beginning to cause friction. Your group has agreed to use a five-step model for problem solving: (1) identify, understand and prioritize the problems, (2) brainstorm for solutions, (3) select tentative solutions, (4) determine how to implement the solutions (who does what, when), and (5) discuss what people have learned about themselves individually and as a group. The staff has also agreed to set a date for re-evaluation of the solutions.

You are a member of the office staff--proceed with the problem solving!

INTERPERSONAL SKILLS FOR BEING EFFECTIVE WITH INDIVIDUALS AND IN GROUPS

Interpersonal skills are critical for problem solving, and they have been identified as highly desirable by employers. A very recent study, Perspectives on Vocational Education (Chicago United, 1984), found that 94% of 995 employers cited the ability to work with others as the interpersonal skill they most wanted in their workers. One of the conclusions from a survey of 593 secondary vocational training teachers in 32 vocational training program areas (Greenan, 1983) was that "all interpersonal relations skills are very important for success and highly generalizable across all program areas and programs" (p. 57).

Considering the importance placed on interpersonal skills by representatives of business and industry and by vocational educators, they should be part of a pretechnical curriculum. This section of the paper describes specific interpersonal skills which can be learned and guidelines for group problem solving, including an extension of the Five Step Model which incorporates the specific interpersonal skills described below.

SKILL: Awareness of Self and Others

Verbal communication skills can be learned, but a person may be regarded as insincere or robot-like if the skills are thought of as tools to "use" on other people. A very important part of instruction in interpersonal communication is awareness of personal needs and values and also the needs and values of others. Only then will new behaviors become comfortable and natural habits of communication. The important

changes are in how one views oneself and others. The verbal skills will follow with practice.

Values

Some experts believe that most values are acquired by the time a person is about ten years old. Young people are influenced by parents, peers, teachers, and "heroes." Their values reflect what they have learned about right and wrong, good and bad, from interactions with people and lessons from other parts of their environment. Morris Massey presented this point of view in The People Puzzle (1979). He explained that although significant emotional events can produce a change in values, people generally maintain those early values throughout their lives. So if one looks at a cross-section of the population, different values legitimately exist. Consider, for example, values differences between those people who were ten years old during World War I and those who were ten years old during Watergate. Massey gave an example of a factory foreman who realized that working overtime was a penalty for his younger workers, but a reward for his older workers. In getting along with other people, it is important to accept that their values are different rather than to label them as wrong. In problem solving situations, solution strategies which conflict with people's basic values will probably not be effective. For example, people who value their health more than their financial status will not be highly motivated by higher pay to be more productive if unhealthy working conditions exist.

Needs

Most dissatisfactions with people and with situations are the result of one's needs not being met. Some basic needs are security,

belongingness, love, and aesthetic fulfillment. But each person has a unique set of needs which might include, for example, a need to feel important, a need to dominate others, a need to be a follower, a need to have one's way, a need to have others in one's debt, etc. Sometimes people find it difficult to put their finger on what is bothering them about a situation. If they could identify which of their needs are not being met, they would be more likely to be able to find reasonable solutions. One very important need for most people is to feel adequate, and when their adequacy is threatened, they tend to behave irrationally. Sensitivity to one's needs and the needs of others is an interpersonal skill of great importance.

Feelings

Awareness of one's own feelings and sensitivity to the feelings of others is absolutely necessary before knowing how to respond to another person effectively; that is, so that communication does not damage the relationship. In general, feelings fall into four categories: Mad, Glad, Sad, and Afraid. Activities exist for helping people to recognize a range of feelings within each category. A simple example of an activity is to simply list as many feelings as possible. In order of decreasing intensity, some feelings under Afraid are: Panic-stricken, terrified, frightened, threatened, alarmed, worried, anxious, bewildered, uneasy, confused, unsure. As will be explained in later sections, sensitivity to feelings is necessary both for effective listening and for being assertive.

SKILL: Recognizing Problem Ownership

Good interpersonal skills are useful in most situations where two or more people interact--at home, at work, or in social or recreational

settings. They are particularly important, however, when someone is upset. It is difficult to function efficiently with feelings of sadness, frustration, helplessness, etc. If one wants to facilitate communication at such times rather than block communication, it is necessary to recognize which person is having negative or uncomfortable feelings--oneself or the other person. The question, according to Thomas Gordon (1974) is, "Who owns the problem?" The answer to that question determines which interpersonal skills are the most useful for effective communication. When the other person is upset, listening skills are important. When you are upset, the skills to be aware of are assertive statements and self-disclosure statements. These skills are described in later sections. Here are some examples of problem ownership:

Suppose a teacher or a manager or a supervisor perceives any of the following <u>from</u> a student or a worker:

- discouraged about personal progress
- failing to meet a performance standard
- depressed about a death in the family
- not being accepted by peers
- having a conflict with peers
- not being able to compete with more talented peers

It is the student or the worker who "owns" the problem. The negative or uncomfortable feelings belong to the other person, and good listening skills are needed.

On the other hand, suppose a teacher or a manager or a supervisor is faced with any of the following from a student or a worker:

- not completing work

- borrowing something and not returning it
- being habitually late
- not following instructions
- being destructive with equipment
- concealing information
- refusing to cooperate
- ignoring important procedures

In cases like these, very likely the teacher (manager, supervisor) will feel upset and will recognize that he or she "owns" the problem. Skillful assertive statements will be useful here.

SKILL: Avoiding Roadblocks to Communication

Certain kinds of responses are not facilitative when another person is upset or angry. Thomas Gordon (1974) called them "roadblocks." Some of them might be all right when no one "owns a problem," but when someone is upset in any way these responses may block communication. They can convey lack of interest, not wanting to listen, or not understanding what the person is saying and feeling. Roadblocks can convey many negative messages: The person is not a competent problem-solver, the person needs to be led, or the person just is not very bright. These messages can be damaging to a person's self-esteem and to relationships between people. The skill is to understand how roadblocks inhibit communication and to cease using them.

Roadblocks to Communication

Directive Responses

These carry a hidden message that the other person's feelings or point of view are not being considered--that there is no interest in

listening and the situation is to be disposed of in the quickest and easiest way: By telling the other person what to do.

1. Ordering, commanding, directing

   "Stop complaining about the system and concentrate on doing the best work you can."

   "Don't keep making excuses. Just get the job done."

2. Warning, threatening

   "If this situation doesn't improve, I'll have to settle it for you and you won't like my solution."

   "If you don't start reading the assignments, I'll give a quiz at the beginning of every class."

Solution Responses

These are attempts to solve other people's problems for them. So what's wrong with giving advice? First of all, a person who is upset most likely will not even hear the advice. Second, advice is generally given from one's own perception of the other person's needs and that might not be the same as the other person's perception. Roadblocks usually address other people's apparent problems rather than their real problems. By jumping in with advice, the focus of the conversation is taken away from the person with the problem. Advice is O.K. if requested or when the other person is no longer experiencing upset feelings.

3. Advising, offering solutions or suggestions

   "Why don't you give up the weekend job and spend more time with your family?"

   "All you need is more confidence in yourself. Tell yourself you can really do it."

Persuasive Responses

Persuasive responses are attempts to persuade other people to change their feelings, thoughts, or behaviors. Guilt, shame, and intimidation are sometimes the hidden persuaders. A person who is upset wants to have their feelings understood, not denied.

4. Moralizing, preaching, giving "shoulds and oughts"

   "You shouldn't feel guilty about turning someone in. You have a responsibility to the whole group."

   "If you didn't vote, you shouldn't complain about the outcome."

5. Teaching, lecturing, giving logical arguments

   "It's very unlikely that your son is in trouble. Most runaways don't go very far, and they usually come home when their money runs out."

   "If I gave you an extension, then I'd have to give other people an extension also."

6. Reassuring, sympathizing, consoling, supporting

   "Oh, it's not all that bad. Everything will look better in the morning."

   "Sure, you can do it. You always come through in a crunch."

Evaluative Responses

These responses involve a negative or a positive judgment. The other person's actions are evaluated rather than objectively observed. Evaluation can be a legitimate function of a supervisor, a teacher, or a peer in a "problem-free" situation, but it is not effective when someone is experiencing unpleasant or uncomfortable feelings or is really down.

7. Judging, criticizing, disagreeing, blaming

   "You just aren't putting any effort into your work."

"If you'd plan ahead, you wouldn't have all this to do at the last minute."

8. Name-calling, stereotyping, labelling, ridiculing

"All right, Mr. Know-It-All."

"That's the way losers talk."

9. Praising, agreeing, giving positive evaluations

"With as much common sense as you have, I'm sure you're going to handle this perfectly."

"You wouldn't intentionally do anything to hurt anyone's feelings. You're the kindest person I know."

10. Interpreting, analyzing, diagnosing

"You may think you don't want that job, but I think you really do. You're just afraid that you'll be turned down and you don't want to rush into it."

"You're just acting that way to get attention."

Avoidance Responses

These responses are designed to avoid communication about the other person's problems. They convey disinterest or unwillingness to carefully listen.

11. Withdrawing, distraction, being sarcastic, humoring, diverting

"Let's talk about something more pleasant."

"You're making a mountain out of a molehill."

"Come on, let's see a smile."

"You think you've got problems? Let me tell you about what happened to me today."

12. Emphasizing your own needs

"Just think about the position that puts me in."

"I can't do anything about that. I set that deadline three weeks ago so this wouldn't happen."

"That's all I need right now is to start getting a lot of flack from you."

Questioning Responses

Questioning is a very common response. The impulse to ask questions is so ingrained in adults that they are seldom even consciously aware of the purpose of their questions. It is important to be aware of the negative effects questions can have on someone who is experiencing a problem. A good analysis of types of questions, their purposes, and their effects appears in Wittmer and Myrick (1974), Facilitative Teaching: Theory and Practice.

13. Questioning, probing, interrogating, cross-examining

"What made you think you could get away with it?"

"Why are you getting upset?"

"Do you still put everything off until the last minute?"

Interrupting

Interrupting is a major non-listening response and a very common one.

14. Interrupting, interjecting, rushing

"But, don't you see . . ."

"Yes, but . . ."

(Nonverbally shaking head "no" while other person is talking)

SKILL: Listening

When one has identified the other person as "owning the problem," good listening skills are needed. Very few adults have any training in listening skills and they are perhaps the most important skills in interpersonal relations. The first step is to be sincerely committed to hearing what the other person is saying and feeling. There should be a concentrated effort to focus on the other person's thoughts and feelings and not to inject one's own agenda into the interchange. There are many increasingly skillful listening responses one can give, and each step up makes the other person feel more that they are being not only listened to but also understood.

1. Encouraging the Other Person to Talk

Silence. This first step is indeed a skill requiring practice. It requires committing oneself to focus on nothing else but the other person. It is a skill seldom practiced at social events where most people's minds are usually on what they are going to say next and where a lot of interrupting and "posturing" occurs. Communication is usually enhanced by allowing people time to collect their thoughts or perhaps to gather courage to express their thoughts and feelings.

Nonverbal Encouragement. Your body can convey that you are interested in listening. Eye contact conveys that you are being attentive. Turning to fully face the other person is a message that you are giving your full attention. If you were reading or writing, you can close your book or put your pencil down. Be aware of the physical environment. Move out from behind your desk or position yourself so that there is no physical barrier between yourself and the other person. Nodding your

head at times can mean, "Yes, go on, I'm listening." A side-to-side movement can mean, "I'm sorry to hear that" or "That's too bad."

Verbal Encouragement. Very simple statements can encourage a person to talk. "I see," "un-huh," "oh, no!" "wow!" Sometimes more direct encouragement is called for, particularly if the other person is silent for a long time. "Would you like to talk about it?" "Go on," "I have some time right now if you'd like to talk some more," "Do you have time to talk about it now?" "I'd like to hear more about that." "How did you feel about that?"

2. Responding by Reflecting Meaning

When the other person "owns the problem" or is upset, encouragement to keep talking is important, but there comes a time when the listener wants to say something that is helpful.

Paraphrasing. One very effective listening response is simply to reflect back what was said. This leaves the ball with the speaker and gives evidence that listening occurred. It also gives the other person a chance to "hear" what he or she has been saying. It would sound awkward to simply repeat or "parrot" the other person's words, so try to paraphrase so that it sounds natural.

- Other person: I can't stand the way Jones keeps pacing up and down.

  Parroting: You can't stand the way Jones keeps pacing up and down!

  Paraphrasing: Jones' pacing really bothers you!

- Other person: I just don't know how to keep those two people from monopolizing the meeting.

  Parroting: You don't know how to keep those two from monopolizing the meeting.

Paraphrasing: Getting everyone involved is tough when those two talk all the time.

Clarifying, Confirming. Sometimes it is difficult to understand what a person is saying because some crucial information is missing. It can be helpful to ask for more information to clarify what has been said or to confirm that it has been understood.

"If I understand you correctly, you tried to explain your actions, but she wouldn't let you. Then it was after that that you wrote the letter."

"When did all this take place?"

Questions should not be probing and "why" questions should be avoided. For example, "Why do you think he was angry at you?" might be a roadblock to communication. Roadblocks must not be used.

3. Responding by Reflecting Meaning and Feelings

The term "Active Listening" is widely used for the kind of listening which reflects not only meaning but also feelings. Listening for feelings is the key to being empathic. Almost everything a person says is preceded by and is the result of some internal thought or feeling they have. Those thoughts and feelings are encoded into verbal messages and what people say usually is not an exact translation of what they are thinking or feeling. Even a message that sounds very direct like, "You're standing on my foot," really means, "Move! Get off my foot!" Most social beings have some skill with deciding the meaning of verbal messages. It is a rare person who would take literally the question, "How many times have I told you not to slam the door?" The meaning and the feelings are clear: "I'm irritated because you slammed the door!" Through awareness and practice the skill of Active Listening can become

a natural and highly facilitative communication tool. Notice how feelings, as well as meanings, are reflected in the following example of an adult educator's Active Listening skills.

STUDENT: (angrily) Well, here's my project. I hope you like it because it took a lot of work, but I only did it because it was required!

TEACHER: The project was a waste of time for you. (REFLECTING MEANING)

STUDENT: Real busy work! I have better things to do with my time!

TEACHER: You really resent the time you spent on this. (REFLECTING FEELINGS--resentment)

STUDENT: Yes! (pause) Well, it was interesting and I did learn some things. It's just that I can't do this kind of thing in my classroom. My kids would go wild at first and the principal would have a fit.

TEACHER: You wouldn't mind trying it but you're a little afraid of what might happen. (REFLECTING FEELINGS--fear or apprehension)

STUDENT: You bet! In my school, it's a real risk just to put the desks in a circle! Sometimes I wonder why I even bother to take classes and learn new ideas.

TEACHER: I guess it can be really frustrating at times. (REFLECTING FEELINGS--frustration)

In this example, the student was angry and the teacher could have "bought into" the student's problem and responded defensively with a Roadblock like, "Well, if you remember, I told the class to see me individually if anyone had problems with the assignment. You should have done that." Then the conflict could have escalated. Or, the teacher could have dismissed the student's feelings with, "Well, I'm

sure it's a very good project. Sooner or later, you'll appreciate having done this." That could have ended the conversation with the student "turned off" and thinking that the teacher didn't understand and didn't care. Instead, the teacher was alert that the student had a problem. The teacher relaxed and listened to the student's anger, reflecting back meanings and feelings. Two things happened: (1) once the angry feelings were out, the student calmed down, and (2) the real problem came out--not anger at the teacher for requiring the project, but frustration with a restrictive school system.

Active Listening serves many purposes in interpersonal communication, and it is an additional skill to be aware of one's objective when listening. Some points for awareness:

- Dealing with anger. When another person "blows up," it is particularly important for the listener not to react to the precise meaning of what was said, because the angry words most often screen the real problem. If the listener reacts defensively, the listener is focused on self-protection and is not hearing the real problem. It is more useful to encourage an angry person to keep talking than to give put-downs, to argue, or to give rebuttals. With Active Listening, angry feelings subside and are diffused. The real problem usually emerges and the screened feelings become apparent: Sadness, frustration, resentment, etc. The listener might then feel a need to deliver a self-disclosure message; for example, "I do not like to be called names," but such messages are not heard or processed as long as the other person is upset.

- Facilitating problem solving. One must not expect that Active Listening will solve other people's problems for them. Rather, it helps other people to clarify problems for themselves, to assume responsibility for their feelings and actions, and eventually to find their own solutions. Active Listening is also an invaluable skill in group problem solving for clarifying and understanding the individual needs that must be considered when searching for a successful solution strategy.

- Support and rapport. Active Listening is not just for intense or explosive situations. Feelings underlie most of the verbal and nonverbal messages people send to one another, and this is particularly true in the classroom or in the workplace where pressures and fears about learning, competence, acceptability, and control exist for both teachers and students, for both managers and workers. Good listening is contagious and skilled individuals can contribute greatly to the kind of cooperative atmosphere which enhances productivity and the quality of people's personal and occupational lives.

SKILL: Assertive Statements

Listening is important when another person is upset. But when people recognize that the upset feelings belong to them--that they "own the problem"--it is equally important to communicate in a nonthreatening manner. The skill is assertiveness.

Being assertive is somewhere between being aggressive and being passive. Aggressiveness involves trying to get one's own needs met at the expense of someone else's needs. Passivity involves meeting other

people's needs at the expense of one's own needs. Assertive statements do not put the other person down and do not blame or criticize. Compare these statements.

Aggressive: You people don't know what you're doing! This is the second time I've brought this coffeemaker back and it still doesn't work right. If you don't fix it I'm going to write to the president of the company.

Passive: I'm terribly sorry to bother you again, but this still isn't working right. Do you think you could look at it again?

Assertive: There's a problem with this coffeemaker. Repairing it doesn't seem to solve the problem, so I'd like a replacement. . . . No, I don't have any more time to spend on bring it in. I'd like a replacement, please.

I-Messages

One kind of assertive statement is called an "I-Message." Its purpose is to maximize the probability of the other person choosing to change the behavior that is interfering with one's needs. It consists of:

- An objective description of the behavior
- The tangible effect of the behavior on the speaker
- The speaker's feelings
- The preferred behavior or expectation

A substitute teacher found the following I-Message to be effective: "When there's a lot of talking in here during reading (OBJECTIVE DESCRIPTION OF BEHAVIOR), it makes it difficult for me to hear students in the reading group (TANGIBLE EFFECT), and I get frustrated (FEELINGS). It

would help me a lot if you would whisper or not talk at all while you work (PREFERRED BEHAVIOR)."

The significance of the "I" in "I-Message" is that the upset person is "owning" the problem. When "you" creeps into the message, the other person tends to become defensive, because "You-Messages" usually come out as judgmental Roadblocks. I-Messages can enhance communication by clarifying the nature of the problem without attacking the other individuals involved.

PROBLEM SOLVING IN GROUPS

Problem solving in groups is now emerging as an important part of the work world for all levels of employees, not just managers (Pratzner & Russell, 1984). Many companies are involving workers in diagnosing problems and implementing effective solutions. These organizations have implemented programs called "Quality Circle Programs," of which one important element is the Quality Control Circle. Very briefly, Quality Control Circles have these things in common. Size: Preferably five to ten members. Volunteerism: Freedom of choice to join. Meetings: One hour weekly, with exceptions. Skills: Brainstorming, cause and effect analysis, data collection, effective planning.

Japanese industrialists have been using Quality Control Circles since 1960. As many as 11 million workers are involved in the Quality Circle movement throughout Japan, and industries in all of the world's industrialized countries have shown interest in implementing the process. The Lockheed Company's Missile and Space Division was the first United States organization to put the concept into action in 1974 and a $500,000 investment in the program resulted in an estimated savings of $3 million (Lloyd & Rehg, 1983).

The National Center for Research in Vocational Education listed organizations in the public sector which have implemented employee participation groups (Lloyd & Rehg, 1983). Among these are the U.S. Air Force, the U.S. Army, the U.S. Navy, and the Federal Aviation Administration. Also listed were 162 organizations in the private sector. Among these are such major companies as Bendix Corporation, Firestone, G. E. Major Appliances, General Foods, General Motors, Hewlett Packard,

Hughes Aircraft, J. C. Penney, McGraw-Edison, Polaroid, 3M, Union Carbide, Uniroyal, and Westinghouse.

Not only are Quality Control Circles advantageous for productivity in business and industry, they are very effective for problem solving in any organization. Lloyd and Rehg (1983) gave an example of effective use of Quality Control Circles by school districts.

> . . . a midwestern school district has used the QC process to solve problems that resulted from declining enrollments and escalating costs (Rehg, 1982). Ten quality circles made of administrators, faculty, staff, and citizens met to develop solutions which were then compiled and distributed to the ten groups. Consensus was reached, and the proposed solution was then presented to the public for review. The school board adopted the solution essentially as proposed by the quality circles. No complaints were received nor were any grievances filed despite the facts that some teachers were reassigned and some terminated, and that some schools were closed. In contrast, the school board in an adjoining district facing a similar problem made a unilateral decision to close certain schools. In response, a citizen's group filed a lawsuit in an attempt to block the closing.

Pratzner and Russell (1984) have delineated the skills, knowledge, and abilities needed for high-involvement participative work settings (pp. 12-13). Under the skill area Group Problem Solving they list eight sub-categories: Interpersonal Skills, Group Process Skills, Problem-Solving Skills, Decision Making, Planning, Communication, and

Thinking/Reasoning. The specific skills for two of these categories are given below.

Interpersonal Skills

- Self-directed
- Flexible
- Assertive
- Open
- Curious to learn
- Able to share/teach
- Responsible
- Understanding of behavior

Communication

- With individuals
- With groups
- Presentation skills
- Verbal skills
- Writing skills
- Listening skills

The General Motors Employee Participation Groups Member Manual (Kolb & Baker, 1980) is used to train employees to be effective group members. Many of the skills the employees learn are interpersonal skills. Some examples:

Involving Others. You may notice some people getting quiet during a meeting. They may have information or ideas but may be reluctant to break into the discussion. You can "invite" them in. Example: "John, we haven't heard from you yet. What do you think?"

Give Credit--Avoid "Put-Downs." If you borrow another's idea or add to it, give them credit for the basic idea. If you don't like another's idea, avoid criticizing the person. Example: "Mary's idea of using the scrap is a possibility. I like it better than not using the scrap." (Not using the scrap was Paul's idea.)

It is not sufficient for successful group problem solving for a person to be adept at problem solving strategies without also having good interpersonal skills. Unlike individual problem solving, group solution strategies are usually arrived at through processes which require listening, empathy, cooperation, and concern for everyone's needs.

Five Step Model for Solving Problems Resulting from a Conflict of Needs

The Five-Step Model is highly adaptable to group problem solving, whether mutual problems exist for only two individuals or for a group. Some problems center around a Conflict of Needs. That is, the needs of one or more persons are not being met, and a change in the behavior of the other person or persons is necessary to solve the problem. In such situations, the specific interpersonal skills described earlier are necessary, particularly at the first step, as shown below.

1. Understand the Problem
   - One person initiates the process by giving an I-Message.
   - Often, the other person(s) will be defensive or will unveil their own related problems, so the first person must reflect

meaning or actively listen in order for the real problem(s) to be identified. Avoiding roadblocks is critical at this point, particularly if the sharing becomes emotional.

2. Brainstorm for Possible Solutions

   - Suggestions are not to be evaluated, and a skillful person encourages others to contribute ideas.
   - Self-knowledge is important for resisting tendencies to interrupt, to put other people's ideas down, or not to be open to new ideas.

3. Choose a Tentative Solution

   - Although compromise is sometimes necessary at this stage, the needs of both or all people must be met as best as possible. Assertive statements are important if one feels that a solution is not good for all the people involved, particularly for oneself.
   - Active listening is useful for helping others clarify their positions about possible alternatives.

4. Carry Out the Tentative Strategy

   - It is important to decide "Who, does What, When."
   - A very specific time should be set for evaluating the solution, which should be considered a trial solution, perhaps the first of several attempts to meet everyone's needs.

5. Learn

   - As new procedures, routines, or behaviors are attempted, look for opportunities to increase self-knowledge. If the

solution is not working, this is the time to look more closely at your real needs. Perhaps the problem, as you saw it, was not the real problem for you. Maybe you need to change what you are doing. Maybe the environment needs to be changed.

- Evaluate the effectiveness of the solution. The process might need to be repeated, from steps 1 through 5.

Thomas Gordon (1974) calls this process the "No Lose" problem solving method. In most interpersonal problem solving one person "wins" and the other "loses." Examples are: Authoritarian classrooms where teachers "win" and students "lose" or permissive classrooms where students "win" and teachers "lose." Analagous situations occur in business and industry when management and labor become involved in power struggles. The objective of the Five Step Model is to resolve conflicts or to solve problems so that everyone gets some of their needs met.

An example of the No Lose process was given in the diary of one of our students, a teacher who was learning new interpersonal skills and applying them in her classroom.

> There has been a situation in my classroom in which students are absent for a day or several days and don't make up the math assignments they missed. Then when I average up grades at the end of the nine-week period, some students don't have all the grades they should and their grade average is lowered. I decided to discuss this situation with my students to see if we could reach an agreement on this matter. This is how the situation went:
>
> Teacher: Class, I think we need to discuss the matter of not making up math assignments after being absent. When the assignments are not made up, I have to explain to your parents why you math grades are so low, and this is really embarrassing and annoying to me. I would prefer that you make up the assignments, but students haven't been doing so. (I-MESSAGE) I'd like to know how you feel about this situation.

Steven: I don't know which pages I missed. You told me what assignments I had done, but I forgot what they were before I had finished all the assignments.

Scott: I didn't understand all of the assignments, so I didn't do the ones I couldn't do.

Teacher: Some of the assignments you didn't do because you didn't know how to do them. (REFLECTING MEANING)

Scott: Yeah, I guess so.

Steven: I could have finished all of mine if I knew what all the assignments were. I asked some of the other students, but they didn't know.

Teacher: You didn't know what some of the assignments were, so you didn't do them. (REFLECTING MEANING)

Steven: Yes.

Sylvia: We don't have time to catch up on assignments when we've been absent. We have math work every day, and if we finish that, there's not much time left for working on other assignments.

Teacher: You're saying that lack of time is preventing you from getting all your assignments done. (REFLECTING MEANING)

Sylvia: Yes.

Veronica: We have to catch up on all our other assignments that we missed too. I just can't get it all done, especially when I've been absent two or three days.

Teacher: Veronica, you also think that there is not enough time to get your assignments done, especially when you have to also catch upon work missed in other classes. (REFLECTING MEANING)

Veronica: Yeah, but I know we have to do our math assignments in your class too.

Several other students voiced similar opinions about why math work that was missed when they were absent was not made up. After a few more minutes of students expressing their feelings and my Active Listening to them, I summarized our problem: "Well, it looks like the problem for me is people not making up assignments after being absent and my having to give lower grades because of the missing work and explaining this to your parents. You are saying that you don't always know what the assignments are, that sometimes you don't know how to do them because you missed the explanations when you were absent, and when you come back, there is

a lot of work to be made up from all your different classes." (UNDERSTANDING AND SUMMARIZING THE PROBLEM - end of Step 1.)

I then asked for suggestions on how we could solve this problem. (BRAINSTORMING - Step 2.) I wrote the suggestions that were given on the board. They were:

1. Give students a zero if they haven't got the assignment done within a week after they come back to school.

2. Make up a folder for each child and put in it any assignments that the person needs to finish. Teacher would explain any work that the child doesn't understand.

3. Send work home by another student or the absent student's brothers or sisters.

4. Let students work in class on the assignments they missed while everyone else is doing the regular assignment for the day.

5. Call their parents and tell them when students don't make up assignments so they can be expecting them to have a low math grade.

Each solution was then discussed to see why or why not it would be a good solution to our problem. (CHOOSING A TENTATIVE SOLUTION - Step 3.) Most didn't like getting a zero for not completing work. Neither did they like the idea of calling their parents about missed assignments. Many students thought that sending work home by brothers and sisters wasn't good because sometimes it was hard to find them and give them assignments and they may forget to give it to them when they got home. I didn't like the idea of students working in class on missed assignments because then they would miss the work scheduled for the day, and they would be even farther behind.

We talked about solution 2 and everyone felt it was a good one, but a time limit should be set on handing the folders back in with the assignments completed (a week was designated). So we decided to try it. Students would make their own folders, and the teacher would put missed assignments in them. A person who didn't do his assignments would have a conference with the teacher to see what the problem was. A student who lost his folder would be responsible for making a new one and finding out from the teacher which assignments needed to be completed. (CARRYING OUT THE TENTATIVE STRATEGY -- "WHO DOES WHAT, WHEN" - Step 4.)

Students are getting work done in their folders and getting them back so far. There has been no instance of lost folders yet. About two or three people have not been able to finish their assignments within the week limit, especially when they have out of school for several days, but I have asked the class if it is okay to give them a time extension, and they agreed.

> I really like that students are trying to get assignments done because they know that they had a part in making this decision, and they are trying to be more responsible for turning in their work. (LEARN - Step 5.)

This kind of process is used in business and industry when Quality Control Circles engage in group problem solving and the results have been impressive. Lloyd and Rehg (1983) gave examples of the outcomes of some of these group efforts.

- A Quality Control committee suggested a procedure which was initiated by the Purchasing Department at Westinghouse Electronics Systems Center in Baltimore, Maryland. By returning overshipments to vendors at their own expense, an estimated $636,000 was saved.
- Management of a General Motors plant in Tarrytown, New York was considering closing the plant down because of high absenteeism and poor product quality. The number of outstanding employee grievances against management totalled two thousand. Since Quality Circles began to hold meetings to discuss complaints and ideas for boosting efficiency, the number of outstanding grievances has dropped to thirty, and absenteeism has been reduced to 2.5 percent.
- At the Lockheed Company, a Quality Circle developed a method to mold a plastic part assembly in two instead of five steps. The redesigned assembly is lighter and stronger than its predecessor, and has resulted in an estimated savings of $160,000 over the life of the contract. Since 1974, Lockheed's savings from its Quality Control program are estimated at almost $3 million, six times the cost of operating the program.

The Need for Interpersonal Skills for Negotiating

Whether between individuals or in groups, interpersonal skills are central to successful negotiation as described Fisher and Ury in their 1983 best-seller, Getting to Yes: Negotiating Agreement Without Giving In. Negotiations occur in everyday life, as when a person returns a defective product and needs a settlement or when price differences must be resolved. In more formal negotiating processes, individuals represent constituencies and negotiating sessions are sometimes hard-hitting encounters, even to the point of using "dirty tricks." Fisher and Ury, however, advocate an approach that consists of skillful interpersonal interactions combined with assertive skills. Some of the skills they mention are awareness of one's feelings, active listening, and I-Messages. ". . . human beings . . . are creatures of strong emotions who often have radically different perceptions and have difficulty communicating clearly. Emotions typically become entangled with the objective merits of the problem. . . .Figuratively if not literally, the participants should come to see themselves as working side by side, attacking the problem, not each other" (p. 11).

Conclusion

It is clear that the American workplace is placing increasing importance on employee problem solving and that interpersonal skills are needed to be effective in problem solving groups. In addition, most citizens are involved in several groups in their daily lives--in classes they take, in PTA's, in social groups, in church groups--and the quality of their participation would be enhanced by being more skilled interpersonally. That is sufficient evidence to consider interpersonal skills

"basic" and to seriously consider where and how they should be taught in the pre-technical curriculum.

There is a need for a formal curriculum for problem solving skills. Skills must be studied, analyzed, and practiced. At the same time, teachers should acquire these skills themselves so that they will be effective models for students. Active involvement in actual problem solving is invaluable, and this should occur at all grade levels. Here are some examples from our observations.

> We observed a high school biology class in which the problem of too much noise during lab periods was solved by the students in such a way that they monitored themselves and increased their productivity.
>
> We observed the faculty advisor for a high school yearbook use the Five Step Method with a Cooperative Education student who was habitually late to yearbook meetings because of a part-time job. Their mutual solution was to have another student fill the student in with information that was missed because of being late and which was needed to do his job.
>
> We observed a fourth grade teacher facilitating a rule-setting session during the first week of school. Class rules were determined to satisfy students and the teacher, and consequences were agreed upon.
>
> We observed a first grade teacher deal with two students who were disputing the ownership of a red felt pen. She directed the students to go out in the hall, settle the matter, and report their solution to her. They did.
>
> We observed a first-grade teacher patiently sitting by a child who was learning to put the papers from his messy desk in order. The child was learning to make decisions and to be responsible. The teacher said nothing except to occasionally ask, "Does that paper go home or will you throw it out?" The child made the decisions.

Teachers must be prepared to facilitate problem solving whenever the opportunity arises. Such learning experiences with "real" problem solving will be remembered by students above all others.

References

Bloom, B. S. (1984). The 2-sigma problem: The search for methods of group instruction as effective as one-to-one tutoring. Educational Researcher, 13(6), 4-16.

Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. R. (1956). Taxonomy of educational objectives, handbook I, cognitive domain. New York: Longmans, Green.

Boocock, S., & Shield, E. O. (Eds). (1968). Simulation games in learning. Beverly Hills, CA: Sage Publications.

Brown, A. L. (1984). Mental orthopedics, the training of cognitive skills: An interview with Alfred Binet. Champaign, IL: University of Illinois, Center for the Study of Reading.

Center for Public Resources. (1982). Basic skills in the U.S. work force. New York: Human Resources Executive Program.

Chicago United. (1984). Perspective on vocational education. Chicago, IL: Chicago United.

Cornish, E. S. (Ed.). (1979). The future - a guide to information sources. Washington, DC: World Future Society.

Daniels, H., & Karmos, J. (1983). Skills for adapting to change. Springfield, IL: Illinois State Board of Education.

deBono, E. (1982). The learning-to-think coursebook. New York: Edward deBono School of Thinking.

Education Commission of the States. (1982). The information society: Are high school graduates ready? Denver: Education Commission of the States.

Exner, R., & Kaufman, B. (1978). An introduction to logic. St. Louis, MO: CEMREL, Inc.

Feuerstein, R. (1980). Instrumental enrichment. Baltimore: University Park Press.

Fisher, R., & Ury, W. (1983). Getting to yes: Negotiating agreement without giving in. New York: Penguin Books.

Glasser, R. (1984). Education and thinking. American Psychologist, 54(2), 93-104.

Good, T. L., & Brophy, J. E. (1978). Looking in classrooms. New York: Harper & Row.

Goodlad, J. I. (1983). A study of schooling: Some implications for school improvement. Phi Delta Kappan, 13(6), 552-558.

Gordon, T. (1974). Teacher effectiveness training. New York: David McKay Company.

Greenan, J. P. (1983). Identification of generalizable skills in secondary vocational programs. Springfield, IL: Illinois State Board of Education.

Guest, R. (1979). Quality of work life. Harvard Business Review, 57(4), 76-88.

Hayes, J. R. (1981). The complete problem solver. Philadelphia: Franklin Institute Press.

Hearn, J. (1982). More life skills. Canada: Employment and Immigration.

Henry, J. F., & Raymond, S. U. (1982). Basic skills in the U.S. work force. New York: Center for Public Resources.

Johnson, T. W. (1984). Philosophy for children: An approach to critical thinking. Bloomington, IN: Phi Delta Kappa Educational Foundation.

Kolb, D. A., & Baker, R. J. (1980). Employee participation groups member manual. Detroit: General Motors.

Lapointe, A. E. (1984). The good news about American education. Phi Delta Kappan, 65(10), 663-667.

Lemons, C. D. (1984). Education and training for a technological world. Columbus, OH: The National Center for Research in Vocational Education.

Lloyd, R. F., & Rehg, V. R. (1983). Quality circles: Applications in vocational education. Columbus, OH: The Ohio State University, The National Center for Research in Vocational Education.

Massey, M. (1979). The people puzzle. Reston, VA: Reston Publishing.

Molitor, G. T. (1981). The information society: The path to post-industrial growth. The Futurist, 15(2), 24.

National Council of Teachers of Mathematics. (1980). Agenda for action - recommendations for school mathematics of the 1980's. Reston, VA: National Councilof Teachers of Mathematics.

National Council of Teachers of Mathematics. Problem solving in school mathematics: 1980 yearbook. Reston, VA: National Council of Teachers of Mathematics.

Nesbitt, W. A. (1971). Simulation games for the social studies classroom. Glenview, IL: Foreign Policy Association.

Piaget, J. (1952). The origin of intelligence in children. New York: International University Press.

Polya, G. (1957). How to solve it. Garden City, NY: Doubleday Anchor Books.

Pratzner, F. C. (1984). The redirection of vocational education in the comprehensive high school. Journal of Industrial Teacher Education, 21(3), 3-12.

Pratzner, F. C., & Russell, J. F. (1984). The changing workplace: Implications of quality of work life developments for vocational education. Columbus, OH: The National Center for Research in Vocational Education.

Rubenstein, M. (1975). Patterns of problem solving. Englewood, NJ: Prentice-Hall.

Snowman, J. (in press). Learning tactics and strategies. In G. D. Phye & T. Andre (Eds.), Cognitive classroom learning: Understanding thinking and problem solving. New York: Academic Press.

Timpane, M. (1982). Corporations and public education in the cities. New York: Carnegie Corporation of New York.

Whimbey, A., & Lochhead, J. (1979). Problem solving and comprehension. Philadelphia: The Franklin Institute Press.

Whimbey, A., & Lochhead, J (1984). Beyond problem solving and comprehension. Philadelphia: The Franklin Institute Press.

Wickelgren, W. A. (1974). How to solve problems. San Francisco: W. H. Freeman.